# PLANTERS' RECORD

VOL. XXX

A quarterly paper devoted to the sugar interests of Hawaii, and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

JANUARY TO DECEMBER

# THE HAWAIIAN PLANTERS' RECORD

VOL. XXX

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# THE HAWAIIAN PLANTERS' RECORD

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## Electrification of Sugar Plantations*


By George L. Trist


The use of electricity for power and light has become so general on many plantations in late years that it is no longer an experiment. Cheaper first cost, flexibility and low maintenance costs are responsible to some extent for its rapid growth.

It is considered that 3-phase, 60-cycle, 440 volts is correct for the factory, stepping the voltage up in ratio to the length of transmission lines for outside installations.

In selecting the prime movers, a study should be made of the steam requirements in the boiling house, selecting a non-condensing unit capable of operating with good steam economy against the back pressure of the system. Providing the K. W. output of generator can be used, this unit should be of ample capacity to furnish the required amount of steam.

Additional units, if required, would be condensing, designed for best possible steam economy.

### Exciters

One motor generator set of ample capacity to care for the entire station is preferred. There should also be one steam driven exciter set to care for the station in case of emergency, or to start up the station when all power is off with no outside supply.

### Switchboards

No set rule can be applied in laying out the switchboard. Care should be taken that plenty of room be allowed for getting around and behind to make repairs to apparatus, reducing hazard of electric shocks to a minimum. Usually it is good practice to mount the field rheostats directly below or above the machine panels and oil circuit breakers about midway between panels and back wall, using remote control for operation. The panels should be not less than 6 ft. and preferably 8 ft. from the wall.

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

## Selection of Motor Feeders

Motor feeders should be of ample current carrying capacity, consideration being given to distance and line drop. Low voltage at the terminals of induction motors is poor practice and false economy. Much better operation will be obtained by applying correct voltage.

## Overload and Low Voltage Release

Induction motors, 5 H. P. and under, may be safely started by throwing directly across the line, almost any approved double throw safety switch being satisfactory. Motors above 5 H. P. should be provided with some form of oil-immersed starter, auto starter, compensator, or magnetic. The magnetic starter is preferred. Whichever is chosen should be furnished with overload and no-voltage release relays. The overload relays, being set for full load of the motor, will become operative in the event of an overload and automatically return the starter to the off-position, eliminating the possibility of burn-outs from single phase operation, which often occur where fuses are the only protection provided. The low voltage relays become operative with extremely low voltage, or upon power failures, automatically returning the starter to the off-position. With return of power, there is no danger of full line voltage being applied, which is not only dangerous to the motors, but objectionable at the power plant.

## Motors

The Squirrel Cage induction motor is applicable to most all drives in the factory, except in a few cases where variable speed is required, when it is advisable to install the wound Rotor motor with suitable resistance and control apparatus. The Squirrel Cage motor is the cheaper and requires the minimum attention on account of the absence of commutator, slip rings, brushes, or brush rigging.

## Sizes of Induction Motors

Induction motors should be run as near full load as possible at all times to guard against low power factor so prevalent in many factories. This condition is extremely bad when the power end is limited. The generating equipment becomes overloaded with wattless current, resulting in overheated machines and poor regulation over the entire electrical system. In factories with limited power house facilities, it is advisable that motors of 75 H. P. and up be of the wound Rotor type to limit starting current to a minimum and prevent violent voltage surges over the system. In factories not limited at the supply end, motors over 200 H. P. should be of the wound Rotor type. This motor, on account of brushes and slip ring arrangements, should be installed in a clean place.

## Synchronous Motors

Too much attention cannot be paid to the subject of the power factor of the mill load. A low power factor cuts down the effective capacity of the generating plant because it requires the generators to supply a large amount of wattless current, which is of no value to the system. Voltage regulation is poorer, voltage drop is greater, and distribution losses are larger than on a system having a high power factor.

The installation of synchronous motors, to obtain a reasonably good power factor, will eliminate these troubles. These have been used in several installations with excellent results.

They are designed to drive mechanical loads up to their capacities in K. V. A. when operating at 100 per cent power factor, when they will exert a considerable corrective effect. They are of the self-starting type, secured by providing the field poles with a Squirrel Cage winding similar to Rotor winding on induction motors.

These machines are most efficient when directly connected to motor generator sets, air compressors (where same can be started with by-pass open to atmosphere), or centrifugal pumps starting with discharge valve closed, or any machinery not requiring more than 25 to 40 per cent full load starting torque.

Where considerable power is purchased from a central station, a penalty clause is almost always in the contract against power factors below 75 per cent.

## Care and Oiling of Motors

More motors are destroyed from an over supply than a lack of oil. When a motor bearing becomes short of oil, the only thing that happens is that the shaft and bearing freeze, the overload relays operate and the motor stops. After babbiting bearing and cleaning shaft, the motor is ready for service again. On the other hand, when too much oil is poured into the bearings, it is drawn into the windings and results in insulation breakdown and total destruction of the windings.

To eliminate some of the above troubles, motors should be located in clean, dry and accessible places, with ample light for inspection.

## Installations

With open wiring installations, the possibility of trouble and delays is greater than in installations in approved conduit and fittings. While the initial cost of a conduit installation is greater, the maintenance cost more than offsets the initial cost, and, incidentally, a much better looking installation is obtained.

For pipe installations, Sheraduct conduit should be used. It is not good practice to use ordinary galvanized iron pipe as there is no guarantee that this material is free from scale and obstructions on the inside, which are liable to injure the insulation of cables while being installed. It is also extremely hard to form the numerous bends necessary in conduit installations with this material.

When lines have to be run in damp or wet locations, lead covered cable with approved potheads should be used. While the cost of this material is high, it is good insurance.

Care should be exercised in making joints and splicing cable. All wires should be cleaned, and after splice is made, same should be soldered, making a good mechanical and electrical connection, covering with rubber and okonite tape, the number of layers depending on the potential of the feeders. Spliced cables or wires should never be enclosed in conduit pipes.

## Transformers

There are numerous installations where two transformers operate open delta on a 3-phase system, in which the full load output is only 85 per cent of the

transformer rating. The initial cost is somewhat less than with a 3-transformer installation. With the 2 transformers, should one unit give out, the factory would have to be closed down until another transformer is secured, or the damaged one repaired. With 3 transformers, one can very easily be removed from the line and the factory still operate under reduced load until another is secured or the damaged one repaired.

## General

The circuits from a power plant should be run in approved conduits to some centrally located point and distributed through fused safety switches in conduit to the various starters throughout the factory; all safety switches to be properly fused. These fuses are for feeder protection only, the overload relays taking care of the motors.

The following suggestions are made regarding installations:

All motors over 5 H. P. should be equipped with magnetic starters, overload relays, no voltage release and time limit acceleration.

Install all motor safety feeder switches and magnetic control panels in stations located as near load centers as possible. Install circuits from power plant to station bus bars in conduit and into safety switches. All the control panels being located in one room, it is a comparatively simple matter to connect from safety switches into the magnetic control panels. From the various central panels, the motor feeders should be run in conduit to the motors. The start and stop push button stations require very little space and can be located in almost any place in the factory convenient to the operators. Having the magnetic starters all located in one station has several advantages. The whole installation can be supervised by one man; the apparatus can be kept clean and free from moisture; hazard of electric shocks practically eliminated; possibility of unauthorized persons changing overload setting entirely eliminated.

Magnetic starters are used very successfully for remote control of Squirrel Cage or wound Rotor, reversing or non-reversing motors. With the control for Squirrel Cage motors, auto-transformers with several taps for reduced voltage starting are used with magnetic contactors for switching from start to run positions. Time limit acceleration is positive 15 to 25 seconds, according to motor service being allowed for motor to reach synchronous speed before switching from the start to run positions. With the magnetic starter, the possibility of the motors being thrown across the line before momentum has been gathered, resulting in blown feeder fuses, burnt contacts, possible danger to motors, belts, driven machinery, and high initial rush of current at power plant, is eliminated, and, incidentally, loss of production from careless or ignorant operation avoided. Also, it is impossible for the operator to keep starter in running position until starting coils are damaged.

Magnetic starters for wound Rotor motors, reversing or non-reversing, are furnished with 4 or 5 points resistance forward or reverse, grid type resistance being used. These starters have the same protective features as above. With the reversing type, it is impossible to throw the motor from full ahead to full reverse, when the operator throws the master controller from full forward to full

reverse, commonly termed "plugging" in crane service. The only thing that can happen is that the contactor on first point of resistance only closes and remains in this position until the high rush of current subsides when second point becomes operative, the motor stopping and reversing in reasonable time, no damage being inflicted on motors, driven machinery, or power plant. This control is excellent for overhead crane, runway table, or any severe reversing service.

## Motor Driven Centrifugal Pump Installations

Pumping stations usually being located some distance from factory or power plant, a transmission line is necessary. The potential of the line being governed by its distance and load, however, step-down transformers for lighting and power are almost always necessary. The operating voltage would be governed entirely by conditions at the pumping plant. In large plants, the Squirrel Cage motors are objectionable on account of the large starting current taken from the line. The wound Rotor motor should then be considered.

In many installations, water is taken off at a much greater or less head than the equipment is designed for. This is a double error, and where at all possible should be avoided. Taking water off at increased heads, decreases the output, the motor not running at full load, which lowers the power factor. On the other hand, with heads decreased to any extent, while the output is increased, the efficiency of the apparatus is lowered, and the power cost increased. Should the motor not be designed to take care of this condition, there is danger of its being overloaded and damaged.

The wiring of pumping plants should be along the same general lines as the factory.

Each starter, however, should be furnished with integrating watt hour meters. In this manner, it is possible to determine the distribution of power over the system.

For domestic supply pumps with elevated tanks, magnetic control with float switch makes an excellent arrangement; when the water reaches the low level the motor starts automatically, stopping at the high level. In installations of this kind, overload relays and low voltage release for protecting the motors should be furnished; also a check or preferably a double check valve should be inserted in the discharge line. With installations of this kind, a continuous water supply is assured, water wastage from overflowing tanks eliminated, power costs and maintenance costs reduced. All the maintenance necessary is a few minutes of one man's time about once or twice a week to clean and oil the apparatus.

## Lighting of Factory and Pumping Plants

Too much thought and study cannot be given to this problem. Good lighting, correctly distributed, with shades, reflectors and modern gas filled lamps, actually reduce current. The lighting cannot be too good. Plenty of light and better lighting result in better and more work, more satisfied organization and less accidents.

Three wire 220-110 volt feeders should be run in conduit from transformers into fused steel distributing boxes, conveniently placed throughout the factory. The number of circuits per panel would be determined by conditions. The feeders should be fused and distribute 2-wire 110 volts, care being taken to balance as near as possible the 3-wire system. Each circuit should be arranged to carry not more than 550 watts. Almost all factories require some lighting during daylight hours. These circuits should be arranged independently of night circuits, to eliminate unnecessary burning of lamps during daylight hours, increasing life hours of lamps, and saving in current.

## Transmission Systems

Transmission lines vary with conditions; length of line, load, and potential desired must be considered. In laying out transmission lines on plantations, it is good practice to keep the line, if at all possible, out of cane fields. While burning off cane, the lines, hardware and insulators are often damaged. When the lines must pass through cane fields, consideration should be given the Bates steel poles, which are inexpensive, easy to erect and eliminate the possibility of total line destruction in the event of accidental fire with no prepared firebreak. The only objection to the steel pole is the fact that in the Islands, it is found very necessary to wire brush and paint them at least once each year to prevent rusting.

For general transmission purposes, butt treated cedar poles are favored.

Trouble has been experienced with burned cross arms and pole tops, where lines were running close to sea. This trouble was successfully overcome by bonding.

In erecting transmission lines, a good mechanical job should be insisted upon, care being given to depth of holes, and proper tamping of poles. Angle poles should be securely guyed.

Where transformers are installed, some approved fused cutout should be inserted in the primary lines.

The secondary from lighting transformers should be run 3-wire 220-110 volts with the neutral grounded at both ends.

Transmission lines should be provided with some suitable air switch so that the line can be disconnected from the system for making repairs, or in case of line trouble.

Transmission lines should be provided with approved type lightning arrestors. The cost is small against the protection afforded.

## Plantation Camp Street Lighting

Where camps are located close to mill or power plant, series lighting controlled from the plant is the best arrangement. Where camps are widely scattered, the cost of the series system would be prohibitive. As an alternative to the series arrangement in outlying camps, where more than one lighting transformer is installed, a cheap multiple installation can be made by tying the third or neutral wire of all transformers together, necessitating the running of one only additional wire. This arrangement with time clocks gives good service. With only one

transformer available, the time clock is the only solution. The clock can be set for operation on or off at any time desired, eliminating the possibility of light burning during daylight hours.

### Plantation Camp Metering

It is advisable to meter all camps in preference to establishing a flat rate system. It will be found that the power consumption with a metered system is very much less than with a flat rate system, because the user will be much more careful in his use of the current if he finds that careless usage increases his power bill.

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## Irrigation Pumping Equipment for Plantation Use*

By E. B. Devoy

Until very recent years the expenditure of any money for the improvement of plantation pumping equipment has been looked upon by most plantation executives as a very necessary evil. Efficiency in a pumping station was unheard of and the engineers, whose unhappy lot it was to try to convince the plantation managers that by spending money they could save more than they spent, had some very hard sledding. This state of affairs was not due to any animosity on the part of the managers but rather to the fact that it was difficult for them to see any tangible results after making the expenditures such as could be shown by spending money on the factories.

Today there are a few plantations whose pumping stations are in no better condition than they were 15 or 20 years ago, but the majority of the larger plantations have put their stations in a condition that is second to none on the mainland.

### Steam Stations

The majority of steam stations in the Islands contain Riedler type pumps driven by Corliss engines, which range from simple to quadruple expansion condensing. Most of the pumps are what are known as the "Extended Type," having the water end located back of the steam cylinders, the plungers being driven by extensions of the piston rods through the back cylinder heads. This type of pump was the recognized standard until 1905 when the "Opposed Type" was first built. The extended type of pump permitted the use of ordinary power engines which were easily adapted to pumping engine work by extending the piston rods and did not necessitate the manufacture of special steam ends. It was not until 1909, however, that the advantages of the opposed type pumping engine were sufficiently recognized by water works engineers that the discontinuing of the manufacture of the extended type was justified.

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* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

As stated above, the extended type of pumping engine owed its popularity to the fact that it was a comparatively small matter to manufacture it by making slight changes in standard power engines, thus obviating the necessity of special steam engines for pumping work. This arrangement had several disadvantages. Power engines are designed for comparatively high piston speeds, but pumping engines necessarily operate at much lower speeds. The valve ports of higher speed units are large and frequently double ported, resulting in large clearance spaces. Owing to the higher speeds it was also necessary to use a much heavier type of steam valve gear and drive than would be required for a slow moving unit. Similar objections were met with in other parts of the steam engine; the bearings and pins were unnecessarily large and the weight was correspondingly increased. The arrangement of the water end tandem to the steam end requires the use of strut pieces between the steam cylinders and the plunger chambers, thus transmitting any expansion in the steam cylinders when hot to the water end and setting up unnecessary strains in the water end material. In Hawaii, a great many of these units are located some distance below ground level. On account of the great length of the extended type of pump its installation below ground level today would be prohibitive due to the high cost of labor, concrete pits, etc.

It was this high speed engine that was largely responsible for the popularity of the Riedler type water end. The Riedler valve with its mechanical closing device permitted quiet operation at a much higher piston speed than could be obtained with an automatic valve pump. The high speed, however, did not make a cheaper installation as the saving in small steam end was practically offset by the expensive Riedler water end. Of late years very few sales have been made of Riedler pumps, practically the only purchasers being the city of Chicago and the Solvay Process Company of Detroit.

## Duty

While there are no figures available as to the original duty guarantee of these old pumps, it is conservative to say that on the compounds the duty ran from 110 million to 120 million foot pounds per 1,000 lbs. of steam and the triples from 120 million to 135 million foot pounds. The modern compound with 175 lbs. steam pressure and 75 degree superheat will show a duty of approximately 163 million foot pounds. A recent test made on a modern vertical triple expansion engine showed a duty of over 200 million foot pounds per 1,000 lbs. of steam. In the field of steam pumping machinery the trend toward higher steam pressures and temperatures has been along lines closely paralleling the development in large power installations. In addition to the improvement in economy due to increased pressures and temperatures, many of the later installations of reciprocating pumps are taking advantage of the gain due to the application of steam extracting feed water heaters to improve the overall economy. Stations sometimes find considerable difficulty in maintaining a proper feed water temperature. This situation is very satisfactorily taken care of by the use of a closed coil heater placed in the exhaust pipe and a second heater arranged to extract steam from the working charge in a receiver.

This will naturally give a lower duty per 1,000 lbs. of steam, but will increase the duty per million B. T. U.'s supplied, which in the final analysis is what the owner is directly interested in. Heaters of this type were installed on a vertical triple expansion engine in the Riverside Station of the city of Milwaukee. Tests were run with the heaters in service and out of service with the following results:

WITH HEATERS OUT OF SERVICE

| | |
|---|---|
| Duty obtained, million foot pounds per 1,000 lbs. steam | 205 |
| Duty obtained, million foot lbs. per million B. T. U.'s supplied | 173.5 |
| Steam consumed per I. H. P. hour, lbs | 9.16 |

WITH HEATERS IN SERVICE

| | |
|---|---|
| Duty obtained, million foot lbs. per 1,000 lbs. steam | 203.5 |
| Duty obtained, million foot lbs. per million B. T. U.'s supplied | 183.5 |
| Steam consumed per I. H. P. hour, lbs | 9.27 |

This shows with the heaters in service a loss of 1½ million foot pounds duty per 1,000 lbs. steam and a gain of 10 million foot pounds duty per million B. T. U.'s supplied.

## Centrifugal Pumps

The subject of centrifugal pumps was very ably presented at the 1924 annual meeting of this Association, and it would be useless for the writer to try to improve on what has already been written. There are, however, a few points that may profitably be brought to the attention of the plantation engineers. In order that we may have a clearer understanding of the different types of centrifugal pumps the following definitions are given:

*Rotary Pump:* The rotary pump, while of a rotating type, is a displacement pump and should not be confused with the centrifugal type of pump.

*Turbine Pump:* A turbine type of centrifugal pump is one in which the impeller is surrounded by a diffuser containing diffusion vanes which reduce the velocity of the water leaving the impeller, transforming velocity head to pressure head.

*Volute Pump:* A volute type of centrifugal pump is one in which the transformation of velocity head to pressure head is taken care of by a spiral shaped casing instead of by using diffusion vanes.

*Multi-stage:* The multi-stage pump consists of a casing with two or more impellers placed in series on the same shaft. Multi-stage pumps are built either with or without diffusion vanes. In the multi-stage pump the water is forced from the discharge of one impeller to the suction of the next by means of reversing channels. These channels usually have directing vanes to guide the water and prevent its rotating.

*Series Pump:* By series pump is meant either one of two things. Either two single stage pumps are mounted on the one shaft with the prime mover, or there are two separate and distinct pumping units in series. In either case, the discharge line from the first pump serves as a suction line for the second.

*Propeller or Screw:* Propeller or screw pumps are similar to centrifugal pumps excepting that the flow of the water is axial instead of radial. These pumps are usually used for pumping a large volume of water at a low head. The efficiency of a screw pump is generally low.

*Nozzles:* The taper portions of the pump between the case proper and the discharge flange and the case and the suction flange are usually referred to as the discharge nozzle and suction nozzle respectively.

A centrifugal pump, due to its low initial cost, low maintenance and low operating expense makes an ideal installation where the head and capacity are constant. When an engineer finds it necessary to purchase a centrifugal pump, he will be well repaid if he devotes a little extra time in analyzing his requirements for head and capacity. This can be readily appreciated by bearing in mind that the pump manufacturer will design and build the pump to meet the engineer's specifications as to head and capacity, and it will be at this point that the pump will show the highest efficiency.

A single stage centrifugal pump is rarely built, except in the larger sizes, to deliver water to more than 200 feet head. The most remarkable exception to this is a 46.5 M. G. D. pump installed in Italy. This pump is delivering against a head of 498.6 feet with an efficiency of 81 per cent.

The idea of placing double suction single stage pumps in series is of comparatively recent origin. This arrangement usually gives a better overall efficiency than can be obtained with the multi-stage pump, although there are cases where the opposite is true. One of the most common sources of trouble experienced with the multi-stage pump is that caused by excessive thrust. This thrust is taken care of by several methods. Most pump manufacturers install in their multi-stage pumps a hydraulic balancing device. Some of these devices have proven successful while others have caused a great deal of grief to the operators. In other pumps the thrust is entirely taken care of by thrust bearings. Another method that is commonly employed is to "short circuit" a small amount of water from the last stage around to the suction side of the impeller. This, at first glance, would appear to be a source of great loss, but the additional work due to pumping this water will usually be far less than that necessary to overcome the friction of a thrust bearing. As the double suction pump is theoretically thrustless, troubles of this nature are practically eliminated in the series pump. It is sometimes necessary to install a high head pump in a pit that is too small to accommodate a series pump. If the depth of the pit is not too great, two pumps, with identical characteristics, may be installed in series, one in the pit and the other at the ground level. With this arrangement the discharge will remain the same and the head developed will be twice as much as with either one of them alone. You will also maintain the high efficiency for which the single stage double suction pump is noted. This method makes a very simple installation for an inexperienced operator, but it also has the disadvantage of decentralizing the units, thereby necessitating considerable traveling for the operator back and forth between pumps.

## Centrifugal Pump Details

Plantation pumping equipment must be designed for heavy duty, especially on the plantations that have a very short rainy season. It is well, therefore, in ordering a centrifugal pump to embody such details in the specifications as will insure continuous service and will expedite repairs when necessary to shut down during the pumping season.

Some pump manufacturers recommend filling the base plate with concrete at the same time the grouting is put in. For a permanent installation this is a very commendable practice, but all pump manufacturers do not leave openings of sufficient area in the base to permit the pouring of concrete. If it is the engineer's desire to fill the base with concrete he should make mention in his specifications that base plate shall have openings of a certain minimum area.

When soft packing is used it is sometimes necessary to shut down to renew packing. The space between the stuffing box end and the bearing housing is usually so limited as to make the removal of the old packing a much longer operation than should be necessary. This work can be greatly expedited by specifying split packing glands. The engineer is then able to remove the gland entirely from the shaft, thus gaining space in which to work equivalent to the thickness of the gland. The material of which packing glands are made differs with the different manufacturers, but the majority of engineers agree that a bronze gland split horizontally is the best type of construction. It will also be well to specify that the ends of stuffing boxes are to be faced off at right angles to shaft. This not only facilitates the even setting up of the gland but will also permit the use of metallic packing at some future date when a satisfactory metallic packing is put on the market.

It would seem, from the various sizes that are furnished, that manufacturers of the split casing type of pump pay very little attention to the shape or size of the heads of capscrews that are used to hold the two casing halves together. During the pumping season it is sometimes necessary to open up a pump for examination or repair. There is nothing more exasperating at this time than to find that the open end wrenches which you assumed could be used for this work will only fit a few of the capscrews and that the rest must be removed with monkey wrenches, pipe wrenches or anything else available. The only remedy for this is to specify that all capscrew heads will fit a wrench of standard opening.

Gland cages or water seal rings, as they are commonly called, have a very important function to perform. Not nearly enough care is taken by the inexperienced operator to see that these rings maintain their proper position in the stuffing box. It is a very common practice during the pumping season, when the packing starts to leak excessively, to add another turn or two of packing to the outside of the stuffing box. Unless care is taken this method soon pushes the water seal ring past the sealing water opening thus destroying its usefulness. Trouble is sometimes experienced in removing these rings for repacking. If all manufacturers would follow the custom of some in making the rings in two halves, the necessity of sometimes removing the top half of pump casing in order to remove the water seal rings would be practically eliminated.

## Pumping Station Accessories

By far the most important accessory to any pumping station is a measuring device for indicating or recording the pump discharge. A discharge measuring device is to a pumping station what a clinical thermometer is to a doctor. It is inconceivable why, at this modern day, many pumping stations are operating without any means of knowing what the pumps are delivering. Many stations depend entirely on the guess of a ditchman or reservoir man. One station that the writer has knowledge of has a weir located at the end of a long pipe line. The company went to considerable expense to install this weir, but they have made no provision to measure the water that is taken from this line at several points along its length to irrigate the fields it passes through. A properly constructed weir is admittedly the most accurate device known for measuring the flow of water in open channels. Its great disadvantage, however, when used in connection with pumping stations, lies in the fact that it must be placed at the end of the pump discharge line. This usually places it a long distance from the pump house, and unless unusual attention is given to noting the flow over the weir, a decrease in discharge may extend over a long period of time before being brought to the operator's attention.

The most satisfactory and easily installed device is the well known Venturi tube. Several different concerns manufacture indicating and recording instruments for use with the Venturi tube, all of whom claim different points in their favor. Probably the best known instrument in the Islands is the Type "M" Register, Indicator and Recorder, manufactured by the Builders Iron Foundry. These instruments when given the proper care and attention are probably as accurate as can be expected. It is advisable, however, that an indicating manometer be kept available for occasionally checking the accuracy of the recorder.

Gauges, both pressure and vacuum, are very essential instruments around a pumping station. From the difficulty experienced in purchasing a reliable gauge it would seem that such an article is not manufactured. For vacuum or low pressure work a manometer can be purchased at practically no increase in cost over a fairly reliable gauge, and when using a manometer the operator knows without any checking that his readings are correct, while if a Bourdon gauge is used a weekly check with a dead weight tester is necessary to insure a maintenance of accuracy.

A steam station requires several instruments not needed in a motor driven pumping station. A steam station should have a draft gauge on each boiler, a recording pressure gauge for boiler pressure, and a recording thermometer for feed water temperature showing the temperature of the water into and out of the economizer when an economizer is being used. There should also be a recording thermometer on the economizer showing the temperature of the flue gases leaving the boiler and after passing through the economizer. Many steam stations have revolution counters that are used for no other purpose than to decorate the gauge board. Without a revolution counter it is too easy a matter for a pump operator to speed the pump up a revolution or two when his discharge meter shows that for some reason or other the pump discharge has fallen off slightly.

A very satisfactory revolution counter for centrifugal pumps is one that is manufactured by S. A. Hasler, of Berne, Switzerland, and handled by C. H. Boulin, of New York City. This is a direct reading type of instrument with a range of 0 to 10,000 revolutions. One of these counters in use at Ewa Plantation shows after one year's service absolutely no wear or loss of accuracy.

Every plantation should have available some type of $CO_2$ indicator. In the ordinary steam pumping station there are so few boilers in service at a time that the installation of a $CO_2$ recorder is hardly justified. There are many types of hand manipulated gas analyzers which can be operated by any person of average intelligence, and the engineer in charge of pumping stations should make it a point to see that they are used regularly. The benefits derived from a periodic use of the analyzer will soon compensate for the labor required.

## Records

During a recent visit to the mainland the writer was very much surprised at the lack of attention given to keeping accurate and complete records of pumping stations. This condition was found in both private and municipal pumping stations. One engineer in charge of several municipal pumping stations went so far as to say that after a pump was installed he never made any tests for efficiency. He stated that if they were in a hurry to furnish water they purchased and installed the best pump available and dispensed with the acceptance test, taking the manufacturer's test as satisfactory. When he was asked for permission to look over his system of keeping records, he replied that their records were so incomplete that nothing could be gained by an examination of same.

Due to the bookkeeping system in vogue on most of the plantations, it is practically impossible for the pump engineer to receive a detailed statement of his repair and operating expenses. He should, however, receive from the main office a monthly statement showing the total expenses incurred on each pump. The engineer should keep his own daily records of all mechanical repairs and all operating details, a monthly recapitulation being turned in to the main office to be incorporated in the monthly financial exhibit.

### PUMPING STATION REPORTS

The following items are reported daily by the engineers on watch at each pumping station:

1. Steam (or Electric) Pumping Station No. ..... Pump No. .....
* 2. From 6 a. m. ....., 19....
* 3. To 6 a. m. ....., 19....
4. Hours Pumping
5. Hours Stopped (Segregated into Time for Repairs and Adjustment or by Order)
6. R. P. M.
* 7. Hours High Lift
8. Head in Feet
9. Suction in Feet
10. Venturi Meter Reading (6 a. m., 6 p. m. and 6 a. m.)
11. Gallons Water Pumped
12. Water Below Engine Center a. m. (and p. m.)

The items below apply to Steam Stations only:

13. Steam Pressure
14. Inches Vacuum
* 15. Temperature of Feed Water
16. Fuel Oil Meter
17. Inches Fuel Oil Used
18. Gallons of Fuel Oil Used
19. Height of Oil in Fuel Tanks
* 20. Draw Circle Around Boilers in Service.—No. 1.. No. 2.. No. 3..
* 21. Oil Car Received. No.... Inches in Dome....Degrees Temp....
* 22. Amount of Oil Received
* 23. Time Oil Car was Received
* 24. Time Oil Car was Emptied
25. Remarks

The items below apply to Electric Stations only:

13. Watt-hour Meter (6 a. m., 6 p. m., and 6 a. m.)
14. K. W. H. Consumption
15. A. C. Amperes
16. D. C. Amperes
17. D. C .Volts
18. Power Factor
19. Temp. of Motor, C
20. Temp. of Atmos. Corresp. to Motor, C
21. Remarks

With the exception of items marked with an * all of these items are transferred daily to a sheet designated "Monthly Record of Steam (or Electric) Pumping Station No. ...."

The items below appear on the bottom of each Monthly Record Sheet (Steam and Electric):

1. Total Hours per Month
2. Previous Hours
3. Hours to Date
4. Average Suction
5. Total Water Pumped

Steam Stations Monthly Record Sheets also include:

1. Bbls. Fuel on Hand on ..... 1st .....
2. Bbls. Fuel received during month
3. Bbls. Fuel—total of above
4. Bbls. Fuel on hand on ..... 1st .....
5. Bbls. Fuel consumed during month
6. Previous fuel consumption
7. Total to date

Equipment and repair records are kept on a 5″ x 8″ card index system. There is also a report sheet on which the pump operator is required to report any repair work done. The repair record is then transferred to the card index system for permanence.

A separate record is also kept in the pump office of all supplies issued to the different stations. There is also kept on a card system a personal record, giving a complete history of each employee.

Undoubtedly, some plantations keep a more complete system of records than others, and it is believed that a standard or uniform system, such as is employed in the sugar factories, would be of incalculable value in enabling the engineers of the different plantations to compare results.

## Testing of Centrifugal Pumps

The Ewa Plantation Company has probably conducted more tests on centrifugal pumps than any other firm or plantation in the Islands. This has been

TESTED BY

## EWA PLANTATION COMPANY, PUMP DEPARTMENT

EWA, HAWAII

TEST NO. 1-2

DATE March 17-24, 1924

TEST ON CENTRIFUGAL PUMP NO. 1

PUMP MANUFACTURED BY —

MOTOR MANUFACTURED BY —

| PUMP DESIGNED FOR M.G.D. | HEAD | R.P.M. | MOTOR H. P. |
|---|---|---|---|
| 12.0 | 70 | 695 | 200 |

| RUN NO. | R. P. M. | SUCTION HEAD: INCHES VACUUM | SUCTION HEAD: LBS. PRESSURE | SUCTION HEAD: FEET | DISCHARGE HEAD: LBS. PRESSURE | DISCHARGE HEAD: FEET | DISTANCE BET. GAUGES | V. H. + − | TOTAL HEAD | M. G. D. | W. H. P. | W. H. METER TIME FOR 36 REV'S: MIN. | W. H. METER TIME FOR 36 REV'S: SEC. | AV W. H. METER TIME FOR 36 REV'S: MIN. | AV W. H. METER TIME FOR 36 REV'S: SEC. | EQUIV. H. P. INPUT | B H. P. | MOTOR EFFICIENCY | PUMP EFFICIENCY | GUARANTEED PUMP EFF. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 695 | 300 | | 3.39 | 28.35 | 65.48 | .66' | − | 69.53 | 11.925 | 145.51 | 2 | 25.1 | 2 | 25.1 | 191.56 | 174.31 | 91 | 83.4 | 82 | 75.9% Overall Eff. |
| | | | | | | | | | | | | 2 | 25.1 | | | | | | | | |
| 2 | 696 | 205 | | 2.31 | 28.5 | 65.83 | .66' | − | 68.81 | 12.1 | 146.12 | 2 | 26.2 | 2 | 26.2 | 190.12 | 173.02 | 91 | 84.4 | 82 | 76.8% Overall Eff. |
| | | | | | | | | | | | | 2 | 26.1 | | | | | | | | |
| | | | | | | | | | | | | 2 | 26.3 | | | | | | | | |

REMARKS AND CONSTANTS

Previous to making run Number 1 no repairs or adjustments of any kind made on pump.

Before making run Number 2 pump was opened up and interior of casing scraped and painted.

K. W. Meter—Westinghouse.

K. T.—2400.

Transf. Ratio—12/1 and 20/1.

carried on mainly to maintain as nearly as possible the same pump efficiency as was obtained when the pump was installed. The testing of a motor driven centrifugal pump is a very simple proposition and requires but a very short time. There is, therefore, no reason why tests cannot be conducted at least twice a year; before shutting down for the rainy months and after the usual winter overhauling. Tests should always be made before accepting a pump to determine whether or not it meets the manufacturer's guarantee. In this connection, it is always well to request from the motor manufacturer a certified copy of the test of the motor that is furnished with the pump.

One of the greatest losses in a centrifugal pump, which increases with the length of service, is what is termed "Disk Friction." Disk friction increases as the surfaces become rougher. The friction of a smooth disk in a rough case is about the same as that of a rough disk in a smooth case. It has been proven that the shrouded type of impeller shows less disk friction than the open one and is in a small measure responsible for the better efficiency obtained with the closed runner type of pump. Engineers will find that by opening up their pump and scraping and painting the interior of the casing they will effect a considerable saving in power. It will also be well in the off-season to polish the impellers. It will usually be found that when the impeller is too badly pitted to polish the cost of a new impeller will be more than offset by the higher efficiency obtained with the new impeller. If a slight error in head was made when the pump was originally purchased, it can be rectified when the new impeller is ordered. This should also result in a more efficient unit.

When the plain type of wearing rings are employed a saving in power will usually result from the occasional installing of new rings. These rings are to reduce the leakage from the discharge to the suction side of the impeller, and in order to reduce the leakage to a minimum very close running fits must be maintained.

In the table is shown the result of two tests conducted on Pump No. 1 of the Ewa Plantation Company. The first test was conducted without improvements of any kind being made to the pump. Before making the second test the pump was opened up and the interior of the casing was scraped and given a coat of paint. The result was a 1 per cent improvement in pump efficiency. There is no question but what a further improvement could have been made if sufficient time had been allowed to remove and smooth up the surfaces of the impeller. The results of this test are given to show how easily it is sometimes possible to improve the efficiency of a centrifugal pump without going to any great expense.

A tentative draft of a Test Code for Centrifugal and Rotary Pumps appeared on pages 213-218 of the March, 1925, number of *Mechanical Engineering*. This draft is subject to correction and addition and when finally revised it is hoped will meet with the same popular approval as did the A. S. M. E. Boiler Construction Code. Operators of centrifugal pumps are urged to use this code as a basis in making and reporting tests.

In this article any preference as to steam or motor driven centrifugal pumps has been purposely omitted. It is obvious that for some services, certain types

of pumps due to service or structural reasons are best fitted. It is generally recognized, however, that the best pump for any service is the one that will do the work in the most satisfactory manner and for the least annual cost.

In closing, the writer wishes to thank W. H. Getz for steam pump data supplied.

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# Chemical Control in Cane Sugar Factories*

By H. A. Cook

In all chemical industries, that are operated on an efficient basis, there must be some method of control for all the reactions entering into the process. The reaction at which the process is most efficiently conducted may be acid, neutral or alkaline, but whatever the reaction, the best results are in nearly all cases obtained within a very narrow margin.

The control of the reaction of the juices going through the cane sugar house has undoubtedly been one of the most neglected and probably one of the least understood phases of the process.

The determination of sucrose or polarization entering the house in the form of mixed juice or cane, the per cent sucrose in the bagasse, in the clarified juice, in the press cake, in the sugar and in the final molasses has received considerable study and is on a fairly uniform and accurate basis. So also are most of the other methods of chemical control, although from time to time improvements are made in these methods.

In the fire room of the sugar house thermometers, pressure gauges and $CO_2$ recorders are vital for efficient control. Scales, venturimeters or electric meters have become a necessity for measuring the amount of fuel consumed. Scales are necessary to weigh the incoming cane, and are also necessary on the mixed juice tanks, at the molasses tanks and in the sugar warehouse. Thermometers and pressure gauges are a necessity on the juice heaters, on the evaporator effects and on the pans. So on, throughout the house, most of the methods of control have been brought to an accurate and scientific basis.

When the mill engineer speaks of the amount of fuel consumed, of the tons cane ground per hour, of the pressure on the rolls or of the amount of live or exhaust steam used, everyone understands the terms used and knows what he is talking about. If the sugar boiler speaks of the purity of the massecuite, of the amount of syrup or remelt taken into the strike, his language is understood. If the chemist speaks of the extraction, of the recovery or of the undetermined losses, everyone knows what he is talking about and usually sits up and takes notice.

All of these terms are intelligible and the methods of control are indicators of the efficiency of the operations. Everyone knows that in all cases the control must be held to a very close margin.

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

Without going into any of the details of the various theories of clarification which are advanced, there remains the fact that this very important phase of sugar making, the clarification and purification of cane juices, is dependent for a vital part of its efficiency upon the chemical aspect. The extent to which this is a chemical or physical process need not be argued, but it can be definitely stated that there should be a basis of control for the chemical side of this process. It might be argued that there has always been a basis and method of control for this side of the process; however, anyone familiar with the control in most cane sugar mills knows how indefinite this control has been.

For the control of the reaction of the clarification process litmus has been the indicator which has served as the basis of control for generations past. Litmus has served its purpose to the best of its ability, but just as many of our mechanical recorders have proven to be inefficient for their purpose, so has litmus proved to have limitations for its purpose.

In Hawaii, a large amount of investigational work on clarification problems has been conducted at the H. S. P. A. Experiment Station. These investigations have shed much light and given much information that heretofore has been obscure or has not been realized.

Work by McAllep and Bomonti (1) on the liming of juices for the best results in clarification gave positive evidence that there was a definite point in reaction at which best results were secured. It was demonstrated in this work that the phosphoric acid content of the juices was a vital element in the factor of clarification. It was shown that if the juice contained the requisite amount of this substance a good clarification could be secured provided the proper reaction was provided for this clarification. It was also found that the maximum increase in purity, for this method of clarification, was obtained at approximately the same reaction as that at which the optimum clarification was secured. This reaction was found to be neutral to or slightly alkaline to phenolphthalein. This investigational work gave the basis for a close control of the reaction of the juice at the liming station.

At the time of these investigations an instrument, or other material for the determination of pH values, was not available at the Experiment Station. This placed the control, for the time being, on the two indicators above mentioned, leaving a large range of reaction uncovered. It has since been demonstrated that a definite relation existed between this reaction and the hydrogen ion concentration or pH to which the juice was limed.

There was little, if any, definite information available as to the behavior of clarified juices during their course through the process, or when held for any length of time at high temperatures. There was no information as to the reaction changes which occurred when these juices were held at high temperatures over a shutdown period or for the length of time necessary in the settling tanks. It was recognized by many that a change in reaction did occur during such period, but as to how much or in what manner this might affect the operation of the plant little was known.

There was, and still is, a great difference in opinion among the authorities on cane sugar manufacture, as to what reaction a juice can be carried and be free from inversion during the course of the process.

The speed of inversion of sucrose in acid solutions has probably been studied more than the kinetics of any other reaction. The large amount of work that has been done in this connection has been confined almost entirely to the study of inversion of sucrose in acid solutions. There is still some conflict in opinion among the investigators as to the actual mechanism of the inversion process, whether 2, 4, 6 or more molecules of water take part in the reaction, just how the hydrogen ion combines in the reaction, or to what extent the reaction is influenced by the thermodynamic activities of the component reactants in the process. However, on one point there seems to be complete agreement, and that is, that the mechanism is a function of the hydrogen ion. Whether the hydrogen ion combines with the sucrose molecule to form a complex molecule which almost instantaneously reacts with water to form dextrose, plus fructose, plus hydrogen ion, or whether there is some other reaction is not agreed, but there is entire agreement to the fact that the reaction is a function of the activity of the hydrogen ion.

It is difficult to determine to what extent the theoretical considerations derived from a study of pure sucrose solutions can be applied to a complex composition such as mixed juice or clarified juice. In the former case the number of variables can be reduced to a minimum which cannot be done in the raw cane juice.

The lack of any such accurate knowledge and the conflicting opinions which existed on the subject prompted the Experiment Station to take up studies along this line.

Data published by McAllep and Bomonti (2) indicated that there is a quite definite reaction in terms of hydrogen ion concentration below which inversion, in detectable quantities, takes place in cane juices when held at high temperatures. This reaction was found to be considerably more alkaline than has been generally supposed to be the case. More comprehensive investigations have been completed by the writer (data soon to be published) that throw considerable additional light on this subject; the results found confirm those already noted.

Similar investigations have been conducted by Walton, McCalip and Hornberger, of the Carbohydrate Laboratory, Bureau of Chemistry (10). The reaction which they indicate as that at which inversion is detected is somewhat lower than found at this Station; however, this is due more to a different interpretation of the subject matter rather than to actual differences in experimental results. The results are in very close agreement with those found at the Experiment Station.

Unpublished data on the study of the rates of reaction changes in clarified juices at high temperatures show that there is a marked similarity in the reaction curves for different juices, although there may be quite a difference in the reaction rate in different juices. These results show that juices

become acid at much faster rates than is generally supposed. Little data is available to give any clew to the cause of this rapid development or increase in the hydrogen ion activity, although there is a wide difference in opinion. Whether it is due to decomposition of glucose in alkaline solutions or the decomposition of other substances, it seems apparent that there is development of an acid. There is a marked increase in the activity of the hydrogen ion, this activity increasing with increase in temperature.

All of these results show that there is need of just as close control of the reaction of the clarified juices as there is of the reaction of the juices at the liming station.

Another factor that at present makes imperative the reaction of the clarified juice as a basis of control is the apparent difference in the resulting reaction of different juices when limed to apparently the same reaction and subjected to the same conditions of temperature. It has been noted that there is a decided difference in the amount of drop in pH secured in different juices between the cold limed juice and the hot limed juice leaving the heaters. In some cases the drop in pH between the cold limed juice and the clarified juice is only from .2 to .3 pH, while in other cases a difference amounting to as much as .8 or .9 pH has been noted. Whether this difference is due to (1), slight differences in the initial pH of the cold juice; (2), to differences in the temperatures in the heaters, or (3), to inherent differences in the juice, has not yet been definitely determined.

These factors make it almost imperative that the reaction of the clarified juice be carefully controlled in order that inversion through the process be avoided.

The mention of inversion losses is often scoffed at, but it is now a recognized fact that inversion takes place in detectable amounts at much more alkaline reactions than has been generally supposed. If the resulting loss, which would accrue to a factory by the inversion of .1 per cent of sucrose in clarified juice, were calculated, the result would be surprising to many factory operators.

There will undoubtedly be developed, in the very near future, some means for the automatic control of the reaction of the juices in the sugar house on an hydrogen ion concentration basis. Such a control has already been developed in many industrial processes. Considerable experimental work has been done in this connection for sugar houses. One of the chief difficulties in this connection has been the development of a suitable electrode. The platinized hydrogen electrode is not suitable for this work. Some of the recent developments in the way of a continuous flow type electrode, constructed of tungsten or other material which will not poison in the presence of organic solutions, and the ability with their development to do away with hydrogen gas is a long step in this direction, but for the present, at least, this control will have to be maintained by some indirect method.

Steps were taken at the Experiment Station to meet this need of a definite and scientific basis of control of the reaction of juices in the mill. This work

resolved itself into finding a method, or adopting a method already in use, to meet conditions in Hawaii.

The use of available potentiometric methods is not adaptable to use in plantation laboratories. This is due not only to the cost of such equipment to individual plantations, and to the skill and care required for their use, but also to the inherent characteristics of the hydrogen electrode when used in organic solutions. These and other factors eliminating the use of potentiometric methods there remained the choice of some colorimetric method or the adaption thereof. The method of Clark and Lubs (3) using comparator tubes with buffer solutions, or the spot test method of Felton (4) as used and described by Brewster and Raines (5), or by Perkins (6), also using buffer solutions, did not seem to possess suitable characteristics for general use in Hawaii.

The main objection to most of these methods was the use of buffer solutions. It was at first found difficult to prepare buffer solutions having the values ascribed to them; these difficulties were previously described (7) and it was thought that this was due to inability to prepare chemicals of sufficient purity. The buffers so prepared required considerable readjustment. This difficulty was later found to be largely due to the inaccuracy of the instrument used in checking the values of these solutions. It was then found that accurate buffer solutions could be prepared if the proper care were exercised in their preparation. However, the preparation of such solutions requires considerable time and labor, as well as such facilities as are lacking in over 95 per cent of the plantation laboratories. It would be an endless undertaking for the Experiment Station to attempt to supply such solutions.

It was then found that buffer solutions could not be counted upon to retain their values for any length of time. Buffer solutions, with indicator added, sealed in sterilized comparator tubes, are supplied by commercial houses, but these are open to more or less the same objections. There are other methods such as that of Gillespie (8) and others by which pH values are determined without buffer solutions, but these methods were considered hardly applicable to plantation conditions.

As some colorimetric method seemed to be most feasible of adaptation, the alternative remained to produce color charts of standard color values. Color charts are procurable on the markets, but these charts do not give very satisfactory results when used in the comparison with such highly colored and often turbid solutions as mill juices. One reason for this seems to be a lack of sufficient concentration of indicator producing too light a color in the charts, while another is the lack of the liquid qualities required for easy comparison.

The preparation of standard color charts was undertaken at the Experiment Station. The object was to reproduce in some satisfactory manner the color changes produced by adding definite quantities of indicator to definite quantities of buffer solutions of known values. Considerable experimental work was required to determine the best indicators and the best concentration of indicator for use with cane juices.

A description of some of the details and some of the difficulties encountered by the Experiment Station in preparing and making available such a method for the plantations of the Islands may be of value to those interested in making available better methods of control for plantation laboratories. Perfection is by no means claimed for the method, but it is considered a valuable asset. As the Experiment Station is conducted for the mutual benefit of all of the Hawaiian plantations and does not participate in commercial work, the charts as developed by the Station and to be described, are available for distribution only among the plantations of the Islands. The amount of material prepared for this purpose was only sufficient for local distribution and replacement.

The indicators proposed by Clark and Lubs (3) were found most suitable, the concentration of indicator solution being the same except for phenol and cresol red which was changed from a .02 to .04 per cent solution. The most definite color changes were secured by using 4 drops of indicator to 1 cc. of solution.

Standard color charts had been prepared and were in use at Crockett refinery, but no data on the preparation or the materials used was available, so that the work at the Station had to proceed without the benefit of other experience. The work was greatly handicapped in that it was being carried out at such great distance from any satisfactory source of supply of materials.

The color changes of phenol and cresol red were first reproduced. These colors were made in oil on artist's canvas; very good colors were made in this manner, but they had the common fault of such colors, namely, lacking the brilliant liquid quality shown by the solutions from which they were prepared, thus making comparison quite difficult. Two serious errors were here committed; the effect of the glass to be used in covering the colors was not taken into consideration; this proved a much more serious factor than would at first appear, for the inherent color in the best grade of glass, procurable locally, considerably altered the colors; the second error was that a source of supply of a good grade of glass was not established, consequently different lots had a different effect on the colors.

About this time it was learned that the colors in use at Crockett were made from dyed celluloid. No data was available as to the process, as the work was done by an outside firm. Experiments were started on this line and proved a difficult task without any knowledge of dye stuffs or dye processes. Small quantities of material were finally produced covering the color range of phenol and cresol red.

The two errors made in the previous work were corrected. A supply of very satisfactory crystal glass had been secured. In order to further obviate any influence due to the glass the color matches were made upon the proper background and through the glass, that is, the dyed celluloid, when covered with glass, was brought to as near the desired color as possible. However, another error was committed in that the supply of celluloid and its composition was not investigated. When the local stock of material was exhausted, new supplies had to be located; these differed so much in texture, composition and

affinity for dye that the previous formulas would not produce anywhere near a similar color.

A new type of material was secured after considerable time and investigation which had many decided advantages over celluloid. This material took dye much more readily and without the use of a hot bath. This latter factor was a decided advantage, for the temperature of the dye bath was an important factor in dyeing celluloid. The bath had to be hot enough so that the dye would permeate the material, and yet guarded so that it did not become too hot resulting in the material turning opaque.

New formulas had to be worked out for this material, but with the experience already gained and the fine working quality of the new material, the colors for phenol and cresol red were duplicated in a small part of the original time.

About the time the second reproduction of these colors was completed a new Leeds Northrup potentiometer was secured by the department. After being installed and thoroughly checked it was found that the previous instrument was in error to the extent of from .2 to .3 pH and that the results obtained by the use of the standard colors were in error to the same extent. This necessitated a complete revision of the colors for these two indicators.

Standard colors were also made up for brom thymol and thymol blue which gives a very complete range for nearly all reactions encountered in the cane sugar house.

Many difficulties which are not here enumerated, were met with in the development of the method and the making of the standard charts. It was a matter of considerable difficulty to secure a supply and a source of supply of uniform reaction plates. Plates having depressions 7.5x20 mm. were required. Coors Porcelain Company is now making these plates. The indentations of the color reaction plates used in practice must be the same size as those from which the colors are prepared. Certain other conditions which are taken up in the instructions must be followed.

There is some justifiable criticism toward the use of any colorimetric method. There is in this method. The use of the potentiometer is far from being free from its limitations in this field. Several factors have arisen which have given considerable trouble in the use of these instruments. There is much yet to be learned in connection with the use of the hydrogen electrode (9).

Inasmuch as the buffer solutions are eliminated and the color charts are made the basis of the values, a certain personal element enters into the determination. Even in view of such limitations as may be inherent in the method, it is a big step in the right direction, and results can be secured that are very close to those secured by the use of the potentiometer.

This method has been in use in Hawaii only during part of the present grinding season; the charts have been distributed to between twenty-five and thirty plantations. Some of the chemists have taken up their use in a very serious manner and many interesting points in factory operation are being brought out by their use. It makes a very simple method for the reaction con-

trol besides making it possible to place the results of different factories on a comparable basis and in terms of expression comprehensible to all.

Where the method is used as a means of routine control irregularities in liming are immediately detected. It has shown that the liming practice of some factories is very regular while that of others is very irregular. As an instance of this, the results of one factory show that the liming can be held to within very narrow limits. At this factory, out of some 150 routine samples, there was a maximum variation of only .5 pH and only 12 of the samples varied to this extent. The method has in other instances showed up very irregular liming practices, as, at one factory the reaction of the clarified juices showed variations from pH 5.4 to 8.2. Many factories have greatly reduced the amount of undetermined losses by careful attention to the reaction of the juices going through the house.

A gain of .3 in purity in the clarified juices is credited to the use of the method by the chemist of one of the progressive plantations. This gain is due to the ability to maintain a much greater uniformity in the reaction of the juices. At this factory it is reported that at the beginning of the control less than 60 per cent of the juices were at the desired reaction. Within less than two weeks this percentage was brought up to 85, and very shortly over 95 per cent of the juices were maintained at the desired reaction. This one gain at this one plantation would more than pay all expenses of the investigational work in producing the charts and the cost of their production.

Another instance of economy gained by attention and application of experimental data is the cutting down of losses over shutdown periods. Many factories that have suffered severe losses over these periods and others that have been to considerable expense in the use of preservatives have been enabled to eliminate or materially reduce these losses and cut out the use of preservatives. This is accomplished by careful attention to the reaction and the temperature of the juices entering the settling tanks and the proper insulation of the tanks.

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Sugar, 27, 172, (1925).
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# Irrigation Water Seepage Losses*

By Joel B. Cox

If we think of a sugar plantation as a plant for transforming certain natural assets into a marketable product, raw sugar, its efficiency is measured by the extent to which these natural resources are utilized as against the wastage which they suffer. Of first importance among these natural resources are:

Labor,
Soil and its fertility,
Water,
Sunlight,
Atmospheric temperature, humidity, etc.,
Fertilizer.

It is water that we are now considering. All our irrigation water reaches the Islands in the form of rainfall, and as yet we have discovered no way of controlling either the amount or the time of its receipt. We may thus take this as the starting point of our study or the 100 per cent of maximum efficiency. From the time when it first reaches the surface in the form of rain, this water is subject to rapid and continuing depletion.

A part escapes to the sea in surface runoff, a part is re-evaporated from the ground surface, and a part transpired by the vegetation on drainage areas. Of the remainder, part disappears from the surface and through deep percolation reaches the ground water system, and another part is taken into our surface irrigation system for storage, transportation and eventual use in the fields. Of the ground water, much the greater fraction succeeds in percolating either to the sea or to that great body of brackish water which underlies the thin floating film of fresh ground water of which we can make use. So, evaporation and percolation have enormously depleted the supply from the rainfall before we ever get our hands fairly on it, either by diversion of surface streams or by pumping ground water, and when we think we have it, we find its powers of escape are by no means exhausted. It escapes from the beds of our reservoirs and ditches to an enormous and only too frequently unguessed amount, and the amount delivered at the margin of our fields is seldom over half that of our visible supply. Even after we start to apply it and turn it fairly into the field, our troubles are by no means over, for the slippery stuff pays no attention to the imaginary surface forming the lower boundary of the root zone of the cane, but persists in its downward path offering the cane rootlets only a bare chance to grab at it in passing. So, of all the water which falls in the form of rain, only a tiny and a rapidly vanish-

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

ing fraction do we succeed in conducting to its point of usefulness, the absorbing rootlets of the cane.

But this tiny percentage is of the utmost importance, and in few parts of the world is water of higher value for agricultural purposes. About 50 per cent of the Hawaiian sugar crop is grown on plantations on which water is the limiting factor in production. On such plantations additional water is worth exactly what you can get for it, that is, the net value of the additional sugar produced by its use. This value is almost always very high. With ordinary prices of sugar, it will usually fall between $20. and $100. per million gallons of water delivered to the field. Even with the other plantations whose production is largely controlled by land area or other factors, if they irrigate at all, their water is worth to them what it costs to get it, and if all sources of expense are included this will often reach unexpectedly high figures. It is seldom that water on an irrigated plantation does not exceed in value $10. per million gallons at some time during the year.

We thus have the situation presented, of the very valuable physical substance, water, reaching the Islands in great profusion, freely and without price, and escaping with such ease and rapidity that we are eternally in want for it. Every bucketful we can save in the right place and the right time will increase our crops, our income and our prosperity by just so much. With enormous losses occurring all around us, the opportunities for preventing them with profit are many and varied, but the elusive character of the substance and the insidiousness of its wastage make the task one requiring painstaking care, constant vigilance and high skill.

It will help at this point to consider a case of the utilization of the rainfall from a single Hawaiian watershed, which has been somewhat completely measured. We can here determine the relative magnitude of the various losses it suffers and find the points of attack on the problem of its conservation which offer the greatest opportunity for economic success.

The upper watershed of the Wahiawa Stream on Kauai has a drainage area of 2.64 square miles and a mean annual rainfall of 170 inches. The average runoff is 10.7 million gallons per day or almost exactly 50 per cent of the rainfall. Of this amount 77 per cent is diverted for plantation use, a very high percentage, made possible by large storage facilities on the plantation and an intense demand for water. Of the 85 inches which disappear from the surface probably half is evaporated and transpired, though this figure is highly uncertain. Using this figure for the entire drainage area above our pumps, we find that we are recovering from wells and tunnels about 15 per cent of the total underground flow. The losses in the plantation ditch and reservoir system are measured and we may form the following water balance sheet, showing the final destination of the rainfall from this watershed:

TABLE 1

| Part of System | Per cent water lost in terms of that entering | Per cent lost in terms of total amount | Balance retained per cent of total amount |
|---|---|---|---|
| Watershed transpiration and evaporation | 25.0 | 25.0 | .... |
| Floods to sea | 11.5 | 11.5 | .... |
| Deep percolation | 25.0 | 25.0 | .... |
| | 61.5 | 61.5 | 38.5 |
| Recovery by pumping | 15.0 | 3.8 | 42.3 |
| Seepage in diversion ditches | 6.0 | 2.3 | 40.0 |
| Evaporation and seepage in reservoirs | 24.0 | 8.7 | 31.3 |
| Seepage from main distributing ditches | 20.0 | 6.26 | 25.04 |
| Seepage from field ditches | 20.0 | 5.01 | 20.03 |
| Losses in watercourses and heads of rows by W. P. Alexander, H. W. Baldwin | 50.0 estimate | 10.02 | 10.01 |
| Loss by deep percolation under rows | 35.0 estimate | 3.51 | 6.50 |

At this point we are ready to deliver our water to the roots of the cane. What they do with it is another problem.

We thus have 14 parts of the rainfall lost to one delivered, although the watershed is very completely developed both by storage and by pumping. The percolation losses as found for this particular watershed are by no means excessive as compared to the usual Hawaiian conditions, so far as my data show.

In considering the above table from the standpoint of an attempt to recover a part of the lost water, we find:

Transpiration, evaporation and percolation from the watershed are unapproachable by any means in current use.

Floods to the sea can be reduced by the construction of reservoirs, which is not our problem of today.

The amount recoverable by pumps can often be increased with sufficient knowledge of the rates and directions of flow of the subterranean waters, and this is intimately connected with the special subject we have in hand.

The seepage losses from ditches are large in total amounts and perhaps most easily controlled of all. Lining the ditches with an impervious material, and location to avoid pervious strata and to give cross sections of low leakage are the most promising methods.

Seepage losses from reservoirs are of great importance where the water is stored for several months, and their reduction frequently offers a field for profitable work.

Losses after reaching the field are more the province of the agriculturist than the engineer, though we can perhaps help out with measurements and data on the various soils which are encountered.

Evaporation losses from reservoirs are uncontrollable except in so far as we may alter the shape and depth of the reservoir. Except in the fortunate case where the reservoir is resting on a permanent ground water table, the evaporation losses are apt to be enormously surpassed by the seepage losses in the average Hawaiian soil.

The prevention of seepage losses from reservoirs and ditches offers, therefore, the most likely zone of profitable work for the engineer and it is to help answer the questions of where and how to locate, and when and how to line that the data of this paper are offered.

The crux of the question of water conservation is accurate measurement. It is usually not the losses which can be seen but those which are invisible that are most costly. If your men on the plantation are even mildly interested in their work, the leaky flume or gate, or the section of ditch with visibly loose banks and with springs appearing below it, will be recognized and repaired. It is the imperceptible underground losses which mount so rapidly into staggering totals. These can only be located by careful measurement. Furthermore the whole problem is fundamentally one of economics. Of course, we could reduce losses to a minimum by lining all our reservoirs with concrete and conveying our water in pipes or concrete lined canals. We could at the same time and in the same way send most of our plantations into the bankruptcy court. We cannot afford to spend two cents for ditch lining unless it will return us more than two cents in increased sugar sold. We must first know exactly where and how much water is being lost, then what it is worth if saved, and lastly, what it will cost to save it. Only if we have reliable knowledge on all three points can we hope to make money through a campaign of seepage reduction.

I do not intend to give much on methods of measurement. That would require a paper in itself. The determination of seepage is done by finding the difference between the amount of water flowing into the section under consideration and that flowing out of it. Any satisfactory method for the measurement of flowing water will do. Weir measurement by a standard weir is the most accurate method available, but is rarely feasible. The current meter is therefore the fundamental tool for most work. The various types of proportional flow and propeller meters on the market are very similar to the current meter in principle, though they differ in their application. The first great difficulty in the accurate determination of seepage is the fact that it must be fixed by the difference between two measurements. Thus, if the loss which is to be measured is 10 per cent of the total flow and each measurement is subject to an uncertainty of 5 per cent, your determination may vary widely from the truth. The second difficulty is that in plantation work a steady flow or continuous condition is rarely met with, and actual losses can usually be obtained only by a series of measurements of considerable length, obtained only by a good deal of labor. The

only point in the operation of the current meter that I care to bring out is that its use is an operation requiring knack and a kind of horse sense in regard to water and its movements that are the result of experience rather than technical ability. The poor quality of the average gaging by a young technical graduate is as marked as the excellent quality of the work of a well taught Japanese of no education. With the latter, however, the required accuracy can be maintained only with systematic checking. It is this which renders it possible to get your data rather cheaply.

Aside from the measurement of losses, as indicated above, is the experimental determination of rates of percolation through various materials. Two methods of testing have been developed. A field test of great utility is to drive as long a section of pipe into the ground as you can; sharpen with a bevel on the outside and drive with any simple hand pile driver rig that can be easily



Fig 1.

arranged. Fill it full of water and observe the subsidence of the column, being careful to keep your rainfall. A laboratory test that gives more rapid and complete results for a wide variation of pressures is to use a pressure cylinder such as that illustrated in Fig. 1. This has the disadvantage that the amount of packing that the material receives is artificially controlled. It is of special value in selecting materials for dam construction.

We are now ready for a presentation of actual figures on the rates of percolation through various soils.

## Table 2

### TEST VALUE OF PERCOLATION COEFFICIENT

| | Values of K in feet per day |
|---|---|
| **Ashokan Dam (page 207 Waterworks Handbook)—** | |
| No. 7 class B earth at 40 lbs. per sq. in | 0.264 |
| No. 2 class A earth at 40 lbs. per sq. in | 0.031 |
| No. 14 very fine sand and clay | 27.3 |
| **Peahi Reservoir, Maui—** | |
| Loose talus | 20.0 |
| Decomposed rock | 3.4 |
| " " | 2.9 |
| Soft, sandy pukapuka rock | 1.44 |
| Hard yellow soil | 0.245 |
| Natural pool in decomposed rock | 0.25 |
| Weathered talus | 0.08 |
| **Tamped Soil for Dam—** | |
| Black large grained surface soil tamped dry | 1.09 |
| " " " " " puddled | 0.008 |
| Red surface under soil tamped dry | 0.68 |
| " " " " " " | 0.007 |
| Yellow hard pan tamped dry | 0.06 |
| Purple soil (clay) | 0.01 |
| " " " | 0.010 |
| **Makawao Reservoir Sites—** | |
| Red clay | 0.001 |
| " " above Makawao | 0.027 |
| " " mixture | 0.123 |
| Semi loam | 2.48 |
| Loam | 0.72 |
| Light brown soil on slope | 6.1 |
| Fine brown loam | 2.2 |
| Gravel bottom | 38.9 |
| Hard yellow brown soil surface 3 ft. down | 2.91 |
| **Reservoir (Kauai)—** | |
| Bottom silt | 0.003 |
| Bottom rock | 0.4 |
| Red soil | 0.9 |
| By total loss test | 0.083 |
| **Reservoir (Kauai)—** | |
| Silt | 0.004 |
| Red soil | 0.004 |
| By total loss test | 0.01 |
| **Reservoir (Kauai)—** | |
| Brown bottom soil | 0.0030 |
| Loose large grained red brown soil | 0.0006 |
| Typical red brown soil | 0.0019 |
| Red clay from rotten rock | 0.0015 |

| | |
|---|---|
| Wahiawa Reservoir— | |
| Top of ridge red brown clay | 0.00075 |
| Slope blackish soil | 0.00169 |
| Pali brownish black | 0.00087 |
| Valley bottom | 0.0015 |
| Nuuanu Reservoir No. 4— | |
| 3.57 in. 55 ft. deep clay assume saturation 20 ft | 0.08 |
| Reddish clay subsoils pressure test | 0.03 |
| Kauai— | |
| Pressure test | 0.08 |
| " " | 0.09 |
| " " | 0.10 |
| " " | 0.11 |
| Tamped moist | 0.12 |
| " " | 0.12 |
| " " | 0.12 |
| " " | 0.13 |
| " " | 0.05 |
| " " | 0.05 |
| " " | 0.04 |
| " " | 0.05 |
| " " | 0.03 |
| " " | 0.04 |
| " " | 0.03 |
| " " | 0.01 |
| Same lightly tamped dry | 0.46 |
| Scarcely tamped | 2.55 |

## Table 3

### SEEPAGE LOSSES FROM RESERVOIRS

| | Depth of water | Loss | | | Value of K |
|---|---|---|---|---|---|
| Reservoir | feet | Feet per day | M. G. per day | Per cent per month | feet |
| 2 | 31 | 0.01 | 0.03 | 2.6 | 0.004 |
| 21 | 34 | 0.152 | 0.427 | 24.3 | 0.08 |
| 1 | 22 | 0.176 | 0.96 | 36. | 0.10 |
| 1 | 27 | 0.322 | 1.99 | 46. | 0.16 |
| 4 | 27 | 0.33 | 0.33 | 34. | 0.16 |
| 5 | 25 | 0.26 | 0.6 | 53. | 0.13 |
| 8 | 45 | 0.25 | 1.6 | 30. | 0.12 |

TABLE 4

SEEPAGE LOSS IN SELECTED HAWAIIAN DITCHES

| No. | Location | Material and notes on construction | Length of section ft. | Flow M. G. day | Loss Per cent per mile | Loss Ft. per day K |
|---|---|---|---|---|---|---|
| 1 | Maui | Best section of large open ditch in average soil | 4,000 | 20 | 0.5 | 0.20 |
| 2 | " | Average for same ditch | 32,970 | 20 | 4.6 | 1.94 |
| 3 | " | Open ditch thinner banks | 20,000 | 40 | 3.17 | 2.92 |
| 4 | " | A poor section of open ditch in ordinary soil | 3,770 | 17 | 9.1 | 3.35 |
| 5 | " | A large well built ditch, largely in tunnel | 20,000 | 20 | 7.63 | 3.87 |
| 6 | " | Dry country, porous rock, tunnels | 30,000 | 30 | 5.28 | 4.86 |
| 7 | " | Surface soil in watersheds, an old open ditch with poor banks | 20,000 | 15 | 14.96 | 7.13 |
| 8 | Kauai | Tight, fine grained red soil, open ditch, small flow in bottom of old ditch | 3,500 | 4 | .... | ..... |
| 9 | " | Same | 8,400 | 5 | 1.9 | 0.034 |
| 10 | " | Small flow in bottom of old ditch in rockier soil than the preceding | 3,500 | 3 | 3.9 | 0.043 |
| 11 | " | Old ditch in fine red soil | 9,000 | 1.9 | 3.7 | 0.07 |
| 12 | " | Old ditch in fine soil, some rocks | 4,800 | 5.4 | 1.4 | 0.28 |
| 13 | " | Same ditch as No. 8 | 3,000 | 18.5 | 4.0 | 1.67 |
| 14 | " | Small ditch in porous brown soil | 3,600 | 0.2 | 86.0 | 2.11 |
| 15 | " | Average soil open ditch | 15,000 | 19 | 6.45 | 2.88 |
| 16 | " | Open ditch around volcanic cone, coarse, scoriaceous material | 6,200 | 10 | 8.3 | 2.98 |
| 17 | " | Red soil with many rocks | 3,600 | 14 | 9.31 | 3.14 |
| 18 | " | Coarse, dark soil | 6,600 | 6.4 | 11.2 | 3.65 |
| 19 | " | Small ditch used inter in granular dark soil | 1,900 | 0.5 | 72.0 | 4.67 |
| 20 | " | Same | 4,300 | 5.0 | 38.0 | 7.00 |
| 21 | " | Loose scoriaceous material in side of cone | 50 | 5.0 | .... | 32.00 |

TABLE 5

LOSS OF WATER IN CANALS NOT AFFECTED BY THE RISE OF GROUND WATER

(Etcheverry)

| Character of material | Feet per 24 hours |
|---|---|
| Impervious clay loam | 0.25-0.35 |
| Medium clay loam underlaid with hard pan at depth of not over 2 to 3 feet below bed | 0.35-0.50 |
| Ordinary clay loam, silt soil or lava ash loam | 0.50-0.75 |
| Gravelly clay loam or sandy clay loam, cemented gravel, sand and clay | 0.75-1.00 |
| Sandy loam | 1.00-1.50 |
| Loose sandy soils | 1.50-1.75 |
| Gravelly sandy soils | 2.00-2.50 |
| Porous gravelly soils | 2.50-3.00 |
| Very gravelly soils | 3.00-6.00 |

TABLE 6

RATES OF PERCOLATION IN CANE FIELDS

| | K feet per day |
|---|---|
| Freshly plowed plant field, just after planting, fine grained red soil | 0.73 |
| Same soil, third ratoon, very hard and solid | 0.03 |
| Fine grained brown soil, plant field, 5 months old, bottom of level ditch | 0.015 |
| Red clay soil, plant field, 6 months old | 0.006 |
| Red clay soil, ratoon field, 8 years old | 0.011 |

These figures are given, not to relieve anyone of the task of measuring his seepage before planning construction to eliminate it, but rather to encourage the getting of such data. Each ditch or reservoir, and even each section of ditch or small area of reservoir bottom, is a problem of its own and the variation in rates of seepage is so great as to require great caution in the use of general figures. They have a real function to serve, however, in crystallizing our experience, leading us to a general idea of what rates of seepage to expect and how various possible combinations of depth, degree of saturation and area of exposed surface will affect the rate of percolation. The units in which we measure seepage losses are of great importance. It may be proved experimentally that the rate of percolation through soils varies directly with the hydraulic gradient, directly as the square of the effective size of the grains (in the case of sandy material) and exhibits a large temperature effect usually given by $\frac{\times + 10^\circ}{60^\circ}$, where $\times$ is the temperature Fahrenheit. For ordinary use, then, the best coefficient for the rate of seepage is the depth in feet of solid water which will flow through a cylinder of soil of constant cross section in which the hydraulic gradient is unity, and at a standard temperature. In my data the temperature was seldom measured and may be taken as 75°.

The hydraulic gradient is sometimes difficult to measure. If a reservoir is suddenly filled and the ground is dry, the gradient is infinity and it remains high for sometime, until the soil surrounding becomes thoroughly saturated. If the ground water is at a great depth below the reservoir, the area is great and the percolation is, hence, sensibly vertical, and the gradient will approach unity as its limit. If the ground water is not so far down and the underground flow must take a flatter slope in order to escape, the gradient may be quite low. In the case of ditches, the gradient will ordinarily be considerably above unity. My measurements indicate that in the absence of other data a gradient of 1.75 may be taken for both reservoirs and ditches.

If we have measured and analyzed the seepage losses on a plantation, the next consideration is how best to reduce them. We may classify our efforts as:

1. Choosing tight reservoirs for our storage as far as possible, and adjusting our storage between existing reservoirs so as to give a minimum of loss.

2. Regulating our pumping ground water levels so as to lose as little fresh ground water as possible.

3. Locating unlined ditches in as tight material as possible.
4. Lining ditches and occasionally reservoirs.

In addition there is the possibility that in cooperation with agriculturists we may work out a practical method in certain soils of reducing the leakage away from the cane root zone by the intentional formation of semi-impervious plow pans, low in the root zone.

The only method of prevention on which we as yet have definite figures is that of ditch lining.

The only successful linings with which I am acquainted are:

Sheet steel,
Wooden planks or staves,
Masonry,
Asphaltic material,
Clay puddle.

For Hawaiian conditions, the first two are usually unduly expensive. and the last two, uncertain and unreliable. Masonry in the form of cut stone set with Portland cement mortar or of concrete holds the field of provedly successful use to the exclusion of all else. My cost data will refer then to this class of construction.

TABLE 7

COST DATA ON DITCH LINING

| Description of ditch and lining | Thickness of lining | Cost Per sq. ft. cents | Cost Per cu. yd. dollars |
|---|---|---|---|
| Tunnels in mountains, large size, very expensive transportation, 1921 | 4″ minimum | 87.6 | 51.60 |
| Same, less expensive transportation, 1922 | 4″ minimum | 51.9 | 30.60 |
| Cut stone in concrete backing, Portland cement pointing, 1922 | 6″ | 45.3 | 24.50 |
| Cut stone, pointed but not backed | 5″ | 20.0 | 13.00 |
| Small ditch, concrete lining, difficult transportation, 1924 | 3″ | 28.7 | 31.00 |
| Small ditch, fairly easy transportation | 3″ | 25.0 | 27.00 |

California practice is to use a much thinner lining. Concrete down to 1½″ in thickness and plaster about 1″ are much used. Our own experience with the thin plaster linings has been anything but satisfactory.

The cost of such a lining will depend more than anything else on the accessibility of the work. With cheap rock and sand and not much trimming of the ditch bank to be done, the cost might be as low as 12 cents per square foot. Under unfavorable conditions, it might be three times this figure.

My present belief is that a thickness of 2½″ of concrete with proportions about 1:2:3 laid without forms on side sloped of 1:1 is the most generally satisfactory and applicable of the various types which have been tried in the Islands.

The last, and in many ways the most important portion of this study, is in the economics of lining. In every case we propose to save a certain quantity

of irrigation water each year by constructing and maintaining a certain amount of lining. We must estimate:

1. The quantity of seepage to be recovered.
2. The value per million gallons of this water.
3. The annual value of the seepage recovered.
4. The first cost of the required lining.
5. The annual cost of the lining.

If the annual cost of the lining is found to be less than the annual value of the water saved, the work is justified, otherwise not. The easiest way to grasp the principles involved is to consider the computations for a representative case. Afterwards we can outline a few general relationships between the elements of the problem.

Let us assume a plantation on which the water saved will be used for more intensive irrigation on the same area. Let us have average cost records which may be subdivided as follows:

TABLE 8

| Item | Present cost of production per ton sugar | Increase in cost of production for each additional ton of sugar from the same area |
|---|---|---|
| Clearing, plowing, preparing and planting | $ 6.00 | ..... |
| Water | 5.00 | $ 2.00 |
| Cultivation | 12.00 | 10.00 |
| Fertilizing | 13.00 | 8.00 |
| Harvesting | 10.00 | 8.00 |
| Manufacturing | 10.00 | 8.00 |
| Marketing | 9.00 | 9.00 |
| Depreciation | 8.00 | 1.00 |
| Sanitation, repairs and other overhead | 12.00 | 2.00 |
| | $85.00 | $48.00 |

If we estimate the future price of sugar at 5 cents per pound or $100.00 per ton, each additional ton of sugar which is produced will net $100.00 less $48.00 equals $52.00 under the assumed conditions.

If, now, our overall duty of water for the assumed plantation plots is as shown in Fig. 2, we are prepared to compute the value of the water which it proposed to save. Let us assume that the average rate of application is 6 m. g. per acre per crop, equivalent to 22 irrigations of 10 inches each. This is at the point A in Fig. 2. At this point the slope of the curve, shown by the dashed line in the diagram, is 0.85 ton of sugar for each million gallons of water applied. The value of each million gallons is therefore 0.85 $\times$ $52 = $44. Let us next consider a section of ditch which carried water during 10 hours a day for 300 days in the year, in which measurements show a loss at the rate of 0.50 foot per

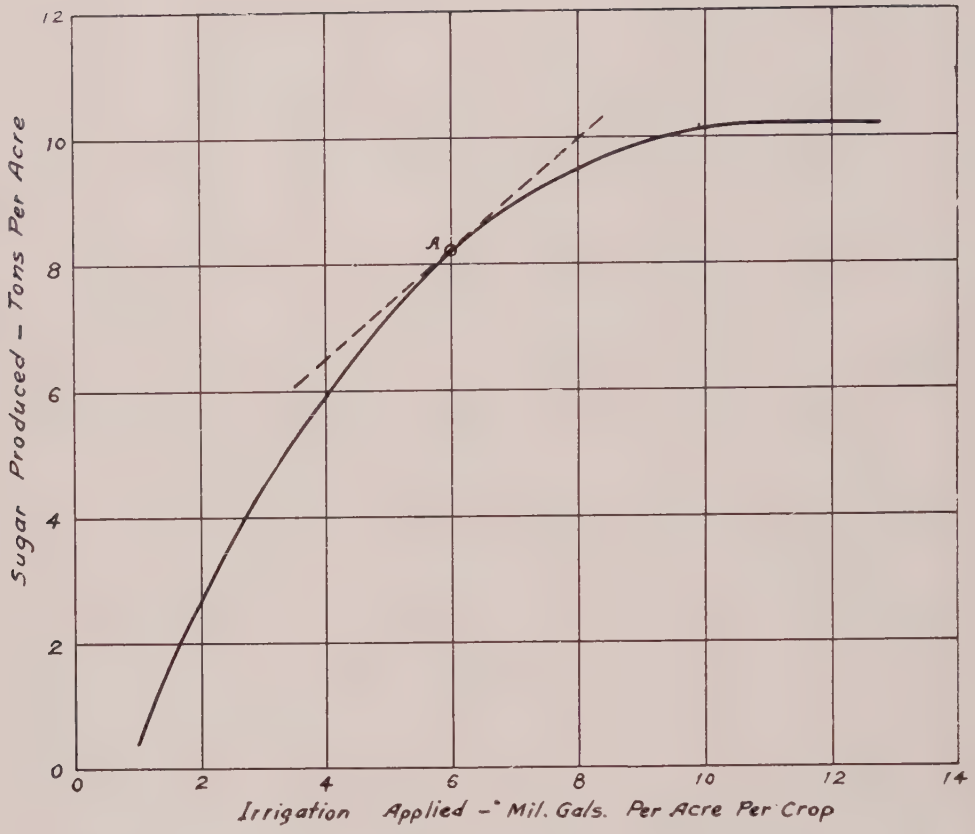



Fig. 2.

24 hours. To line this with concrete is estimated to cost 20 cents per square foot. Taking as a unit 100 square feet of ditch, wetted surface, the loss per year is:

$$100 \text{ sq. ft.} \times 0.50 \text{ ft.} \times \frac{10}{24} \times 300 = 6250 \text{ cu. ft. per year} = 0.0468 \text{ million}$$

gallon per year. $0.0468 \times \$44 = \$2.06$ per year annual value of the water lost.

The annual cost of the lining is computed as follows:

First cost $\$0.20 \times 100 = \$20.00$ per 100 sq. ft.

Annual cost:

| | |
|---|---|
| Interest | 7% |
| Depreciation | 4% |
| Repairs and maintenance | 2% |
| Taxes, etc | 2% |
| | 15% on $20.00 = $3.00 |

The lining in this case is therefore not justified. It would pay for itself if the leakage saved were at the rate of 0.73 foot in 24 hours.

In general, if

V = Value of water per million gallons;
H = Number of hours per day that water is in ditch;
D = Number of days in year that water is in ditch;
K = Rate of percolation in feet of water surface in 24 hours;
C = Cost of lining in cents per square foot;
P = Annual rate of charge on first cost of lining in per cent.

The condition that the value of water saved first pays for the lining is given by:

$$320\,\frac{CP}{HDK}$$

## Table 9

### Cost per Million Gallons of Water Saved by Ditch Lining

C = Cost of Lining = 25¢ per sq. ft
P = Annual Charge = 15 %

| Seepage Saved in feet Per day K | Time Ditch is Holding Water in Hours per Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 500 | 1000 | 2000 | 3000 | 3650 | 4800 | 7200 | 8760 |
| 0.05 | | $2400 | $1200 | $800 | $658 | $500 | $333 | 274 |
| 0.10 | | 1200 | 600 | 400 | 329 | 250 | 167 | 137 |
| 0.15 | | 800 | 400 | 267 | 219 | 167 | 111 | 91 |
| 0.20 | | 600 | 300 | 200 | 164 | 125 | 83 | 68 |
| 0.25 | | 480 | 240 | 160 | 132 | 100 | 67 | 55 |
| 0.30 | $800 | 400 | 200 | 133 | 110 | 83 | 56 | 46 |
| 0.4 | 600 | 300 | 150 | 100 | 82 | 62 | 42 | 34 |
| 0.5 | 480 | 240 | 120 | 80 | 66 | 50 | 33 | 27 |
| 0.6 | 400 | 200 | 100 | 67 | 55 | 42 | 28 | 23 |
| 0.7 | 343 | 172 | 86 | 57 | 47 | 36 | 24 | 20 |
| 0.8 | 300 | 150 | 75 | 50 | 41 | 31 | 21 | 17 |
| 0.9 | 267 | 133 | 67 | 44 | 37 | 28 | 18 | 15 |
| 1.0 | 240 | 120 | 60 | 40 | 33 | 25 | 16.67 | 13.70 |
| 2.0 | 120 | 60 | 30 | 20 | 16 | 12.50 | 8.33 | 6.80 |
| 3.0 | 80 | 40 | 20 | 13 | 11 | 8.33 | 5.55 | 4.56 |
| 5.0 | 48 | 24 | 12 | 8 | 6 | 5.00 | 3.33 | 274 |
| | $40 | $20 | $10 | $5 | | | | |

Table 9 is based on cost of lining at 25 cents per square foot and an annual charge equal to 15 per cent of the first cost. The heavy zigzag lines indicate the limits to which we can afford to line with water worth $5.00, $10.00, $20.00 and $40.00 per million gallons. Summarizing this table in the light of our study of losses in existing ditches (Tables 4 and 5), we see that with ditches which run both night and day throughout the year, most ditches require lining even though the water is not especially valuable. For ditches running 2,000 or 3,000 hours per year, with high water values, the average ditch will require lining, while low values of water would need excessive seepage rates to pay for themselves. The more occasional ditches will ordinarily be lined only when the seepage rate is unusually high and water valuable.

It may be safely predicted that on nearly every irrigated plantation there are few investments which will yield greater returns than ditch lining. It should be done systematically and carefully, and a program of work adopted based on careful measurements so that the heaviest losses shall be the first controlled. The field of reservoir lining is also promising, though the rates of percolation are usually lower here. One point to remember is that other things being equal it pays to line the ditches nearest the field first. To start at the intake end means that much of the water you save is relost in passing through the leaky ditches further along the line. A large field for research is offered in the determination of seepage losses. One particular phase which needs much more work done upon it is the determination of the probable seepage loss from a reservoir basin in advance of its construction. Something can now be done by means of the tests I have described, and I believe the fullest investigation possible should be made in every case before a cent is spent in dam construction. The development of more comprehensive methods which will decrease the margin of error of our estimates of seepage is urgently needed. The aggregate amount of money which has been wasted in Hawaii in reservoirs which will not hold water would have served to pay many additional dividends.

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# Report of the Committee on the Relation of Cane Diseases to Cane Varieties*

By H. Atherton Lee

These Islands are very fortunate in having but few of the infectious cane diseases which are known in other countries. In countries of the Old World particularly, such as India, Java, Formosa, the Philippines, New Guinea and Australia, where cane has been grown for centuries, a number of infectious diseases occur which are not present here as yet.

In a number of these other countries, our commercially grown varieties, H 109, Yellow Caledonia, D 1135, Lahaina, Uba and Badila have been grown

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

under conditions where they were exposed to some of these foreign diseases. It has seemed to this committee that a record of the reaction of such varieties to these foreign diseases would be valuable in the event of the introduction of any of these new diseases to these Islands. A knowledge of the extreme susceptibility of some of our most widely planted varieties also may increase our vigilance in keeping such diseases out. Our Tip canes do not seem to have been grown to any extent in other countries, so that there is little or no knowledge concerning their reaction to foreign cane diseases. A record of the susceptibility of our standard varieties and some of our new seedling varieties to local diseases is also tabulated and may point the direction for some of the breeding work and field administration on the plantations.

In the tabulation we have included two columns, in the first the susceptibility to infection, or, in other words, the readiness with which the variety contracts the disease. In the second column is the degree of tolerance, or, in other words, the degree of injury suffered from the disease. The word immune is used here to indicate total ability to resist infection; a cane immune to a disease is incapable of contracting the disease. The term resistant, as we use it here, indicates that the cane seldom is affected, although infection is possible. It may mean also that once the cane is infected it suffers little from such infection. The knowledge concerning the reaction of the varieties listed to these diseases is either from personal experience or, in some cases, from the literature of other cane countries.

TABLE I

**The Susceptibility or Resistance of H 109 to Infectious Foreign Cane Diseases** [1]

| Name of the disease | Causal Agent | Distribution | Susceptibility to infection | Degree of injury after infection |
|---|---|---|---|---|
| Fiji disease | Unknown | Fiji, Australia, New Guinea, the Philippines | Severe | Severe |
| Gumming disease | *Phytomonas* (*Bacterium*) *vasculara* | Fiji, Australia, Mauritius, Brazil, Porto Rico | Severe | Severe |
| Leaf scald | A bacterial organism unnamed as yet | Java, the Philippines, Australia, Fiji | Severe | Severe |
| Bulaclac | A flowering parasite like a mistletoe, *Aeginetia indica* | China, the Philippines, and Malayan region in general | Unknown | Unknown |
| Sereh | Unknown | Java and Formosa | Unknown | Unknown |
| Streak disease | Unknown; suspected of being a filtrable virus | Natal, South Africa | Unknown | Unknown |
| Downy mildew | A fungus, *Sclerospora sacchari* | Australia, Formosa, the Philippines, Fiji | Moderate | Slight |
| Cane smut | A fungus, *Ustilago sacchari* | India, Java, the Philippines, China; reported from several other countries but needs corroboration | Resistant | Resistant |

| | | | | |
|---|---|---|---|---|
| Pokkah bong | Unknown | Java, the Philippines | Unknown | Unknown |
| Curly top (possibly Pokkah bong) | Unknown | Australia | Unknown | Unknown |
| Wilt | A fungus, *Cephalosporium sacchari* | India, the Philippines and South Africa | Unknown | Unknown |
| Collar rot | A fungus, *Hendersonia sacchari* | India | Unknown | Unknown |
| Polvillo | Unknown | Brazil, the Argentine | Unknown | Unknown |
| Dry top rot | A fungus, *Plasmodiophora vascularum* | Porto Rico | Unknown | Unknown |
| Rust | A fungus, *Puccinia kuehnii* | Java, the Philippines, Formosa, Australia, India | Slight | Resistant |
| Yellow leaf spot | A fungus, *Cercospora kopkei* | Java, the Philippines, Reunion, the Argentine | Slight | Resistant |
| Banded sclerotial leaf disease | A fungus, unnamed, with sterile mycelium | India, the Philippines, Java | Moderate | Moderate |
| Red leaf spot | A fungus, *Eriosphaeria sacchari* | Java | Unknown | Unknown |
| Brown spot | A fungus, *Cercospora longipes* | India, Porto Rico, Trinidad | Unknown | Unknown |
| Black leaf spot | A fungus, *Phyllachora sacchari* | Java, the Philippines | Unknown | Unknown |
| Pestalozzia leaf spot | A fungus, *Pestalozzia fuscescens* | Java, the Philippines | Unknown | Unknown |

In the foregoing table have been listed several diseases of which we have no knowledge concerning their effect on H 109; such diseases have been listed in the table to show the number of infectious troubles which have not yet become established in Hawaii. A great many diseases which seemed of minor importance have been omitted from the list. A top rot described from Java and another from Australia have not been included in this list, since knowledge of their infectious nature is not known to us here in Hawaii.

From the foregoing lists, H 109 is seen to be severely affected by some of the foreign cane diseases. To the diseases now present in these Islands it is fortunately resistant or but moderately susceptible. Eye spot is the greatest drawback to H 109, but, looking at the acreage as a whole, it is but a small proportion of the total acreage which is affected; the condition of most areas in which H 109 is grown is unfavorable for the development of eye spot, so that injury from this disease is restricted. H 109 is not readily infected with mosaic disease, under the conditions of these Islands, and when affected does not suffer as severely as Lahaina or the Tip canes. It is this degree of tolerance to the disease which has caused many planters to disregard mosaic, with the result that, in general, our

[1] Knowledge of the reaction of cane varieties to gumming disease is largely from conversations with D. S. North, of the Colonial Sugar Refining Company of Australia and Fiji. The knowledge of the reaction of cane varieties to streak disease is due to publications by H. H. Storey, Government Mycologist of the Union of South Africa. Knowledge concerning dry top rot of cane in Porto Rico is due to Julius Matz, pathologist of the Porto Rico Agricultural Experiment Station.

irrigated plantations with H 109 now have more general infection than the unirrigated plantations which grow more susceptible canes. It seems to be a conservative generalization to state that H 109 is rather resistant to most of the non-infectious diseases arising from soil characteristics.

TABLE II

**The Susceptibility or Resistance of H 109 to the Diseases of these Islands**

| Name of disease | Causal agent | Distribution | Susceptibility to infection | Degree of injury after infection |
|---|---|---|---|---|
| **Infectious** | | | | |
| Mosaic disease or yellow stripe | Not established as yet but presumably a filtrable virus | All Islands but not all plantations | Moderate | 36% loss[1] |
| Eye spot | A fungus, *Helminthosporium sacchari* | On northern parts of Islands and gullies where light and air movement are lessened | Severe | 0 to 38%[2] |
| Red stripe | A bacterial organism, *Phytomonas rubrilineans* | Kohala district only | Resistant | Negligible |
| Iliau | A fungus, *Gnomonia iliau* | Mauka fields in cold weather | Resistant | Slight |
| Ring spot | A fungus, *Leptosphaeria sacchari* | All plantations | Susceptible | Negligible |
| Pineapple disease of standing cane[3] | A fungus, *Thielaviopsis paradoxa* | Rare; occurs only once in several years and then in very small areas | Susceptible | Affected stalks a total loss |
| **Non-infectious** | | | | |
| Hamakua type of Lahaina disease | Unknown | Not entirely determined; suspect—on windward soils | | Resistant |
| Salt injury type of Lahaina disease | High salt content of soil solution | In semi-arid districts | | Resistant |
| Pahala blight | Unknown | Kau district only | | Moderate[4] |
| Sectional chlorosis | Unknown | All Islands | | Negligible |
| Leaf freckle | Unknown | All Islands | | Negligible |
| Limestone chlorosis | Unknown | Maui, Oahu, Kauai | | Appreciable |
| Cane yellows type of chlorosis | Unknown | Maui, Oahu, Kauai | | Appreciable |

[1] From experiments by Kunkel in which mosaic seed was planted against healthy seed.
[2] Losses depend on situation; more than two-thirds of the H 109 acreage is entirely uninjured by eye spot.
[3] We have few instances where pineapple disease affects germination of seed pieces.
[4] Knowledge of the relationships of cane varieties to Pahala blight is chiefly due to J. C. Thompson, of the Hawaiian Agricultural Company.

In the following table, showing the reaction of Yellow Caledonia to some of the foreign diseases, only such diseases to which Yellow Caledonia has been exposed and observations made will be recorded:

TABLE III

**The Susceptibility or Resistance of Yellow Caledonia to Infectious Foreign Cane Diseases**

| Name of disease | Causal agent | Susceptibility to infection | Degree of injury after infection |
|---|---|---|---|
| Fiji disease | Unknown | Severe | Severe |
| Gumming disease | *Phytomonas vasculara* | Resistant | Resistant |
| Leaf scald | A bacterial organism undescribed as yet | Resistant | Resistant |
| Sereh | Unknown | Susceptible | Less severely affected than Cheribon |
| Downy mildew | *Sclerospora sacchari* | Resistant | Resistant |
| Cane smut | *Ustilago sacchari* | Resistant | Resistant |
| Pokkah bong | Unknown | Unknown | Unknown |
| Curly top | Unknown | Susceptible | Severely affected |
| Dry top rot | *Plasmodiophora vascularum* | Susceptible | Unknown |
| Rust | *Puccinia kuehnii* | Resistant | Resistant |
| Yellow leaf spot | *Cercospora kopkei* | Slight | Resistant |
| Banded sclerotial leaf disease | Sterile fungus | Slight | Resistant |

Except for Fiji disease, Yellow Caledonia is a cane fairly resistant to most of these infectious diseases. In these Islands it suffers less from infectious diseases than almost any variety. It is very susceptible to Pahala blight, but aside from this is comparatively resistant to the non-infectious diseases as well. Pahala blight, moreover, is restricted in extent to very small areas in the Kau district.

TABLE IV

**The Susceptibility or Resistance of Yellow Caledonia to the Diseases of These Islands**

| Name of disease | Causal agent | Susceptibility to infection | Degree of injury after infection |
|---|---|---|---|
| **Infectious** | | | |
| Mosaic disease | Apparently a filtrable virus | Resistant | Severe |
| Eye spot | *Helminthosporium sacchari* | Resistant | Resistant |
| Red stripe | *Phytomonas rubrilineans* | Resistant | Resistant |
| Iliau | *Gnomonia iliau* | Susceptible | Moderate |
| Ring spot | *Leptosphaeria sacchari* | Susceptible | Negligible |
| Pineapple disease of standing cane | *Thielaviopsis paradoxa* | Resistant | Negligible |
| **Non-infectious** | | | |
| Hamakua Lahaina disease | Unknown | | Moderate |
| Salt injury type of Lahaina disease | High salt content of soil solution | | Some degree of resistance |
| Pahala blight | Unknown | | Severe |
| Sectional chlorosis | Unknown | | Negligible |
| Leaf freckle | Unknown | | Negligible |
| Limestone chlorosis | Unknown | | Moderate |
| Cane yellows type of chlorosis | Unknown | | Resistant |

TABLE V

**The Susceptibility or Resistance of D 1135 to Infectious Foreign Cane Diseases**

| Name of disease | Causal agent | Susceptibility to infection | Degree of injury after infection |
|---|---|---|---|
| Fiji disease | Unknown | Severe | Severe |
| Gumming disease | *Phytomonas vasculara* | Slight | Moderate |
| Leaf scald | A bacterial organism undescribed as yet | Resistant | Resistant |
| Downy mildew | *Sclerospora sacchari* | Resistant | Resistant |
| Rust | *Puccinia kuehnii* | Resistant | Resistant |

The exposure of D 1135 to a number of the diseases of foreign countries has not been recorded or observed in as many instances as H 109 or Yellow Caledonia. Most of the observations of the reactions of D 1135 to these infectious agents have been made by D. S. North in Australia, where D 1135 has been grown to some extent for years, or in the Philippines where D 1135 has been recently introduced.

TABLE VI

**The Susceptibility or Resistance of D 1135 to Diseases of These Islands**

| Name of disease | Causal agent | Susceptibility to infection | Degree of injury after infection |
|---|---|---|---|
| **Infectious** | | | |
| Mosaic disease | Apparently a filtrable virus | Resistant | 31 to 41% according to Kunkel[1] |
| Eye spot | *Helminthosporium sacchari* | Resistant | Negligible |
| Red stripe | *Phytomonas rubrilineans* | Resistant | Negligible |
| Iliau | *Gnomonia iliau* | Resistant | Negligible |
| Ring spot | *Leptosphaeria sacchari* | Resistant | |
| Pineapple disease of standing cane | *Thielaviopsis paradoxa* | Resistant | Moderate |
| **Non-infectious** | | | |
| Hamakua Lahaina disease | Unknown | | Moderate |
| Salt injury type of Lahaina disease | Excess salt content of soil solution | | Moderate |
| Pahala blight | Unknown | | Resistant |
| Sectional chlorosis | Unknown | | Affected but injury negligible |
| Freckle | Unknown | | Negligible |
| Limestone chlorosis | Unknown | | Unknown |
| Cane yellows type of chlorosis | Unknown | | Slight |

A notable phenomenon is the resistance of D 1135 to infection with mosaic disease in these Islands, and its resistance to injury or tolerance of the disease once it is affected. In the West Indies, according to H. P. Agee, D 1135 is considered susceptible and sensitive following infection. To some extent, the same

[1] Cases of mosaic disease in D 1135 have been observed to recover and all symptoms of the disease disappear.

is true in the case of Yellow Caledonia; it is one of our most resistant canes in these Islands, while the early attacks of mosaic in Porto Rico were frequently most severe on Caledonia. There would seem to be an opportunity for valuable research as to the reasons for these differences in susceptibility.

Except for its susceptibility to Fiji disease, D 1135 seems to be resistant to most cane diseases, as well as most leaf diseases. It would seem to be very valuable as a parent for breeding resistant seedlings.

TABLE VII

**The Susceptibility or Resistance of Lahaina to Infectious Foreign Cane Diseases**

| Name of disease | Causal agent | Susceptibility to infection | Degree of injury after infection |
|---|---|---|---|
| Fiji disease | Unknown | Severe | Severe |
| Gumming disease | *Phytomonas vasculara* | Severe | Severe |
| Leaf scald | A bacterial agent | Severe | Severe |
| Sereh | Unknown | Some degree of resistance | Moderate |
| Streak disease | Unknown | Susceptible | Unknown |
| Downy mildew | *Sclerospora sacchari* | Susceptible | Moderate |
| Cane smut | *Ustilago sacchari* | Slight | Slight |
| Dry top rot | *Plasmodiophora sacchari* | Susceptible | Unknown |
| Rust | *Puccinia kuehnii* | Resistant | Resistant |
| Yellow leaf spot | *Cercospora kopkei* | Slight | Slight |
| Banded sclerotial leaf disease | Sterile mycelium | Susceptible | Slight |

Lahaina cane or, if we follow Noel Deerr as to synonyms, Otaheite, Bourbon or Louzier cane is very susceptible to a number of diseases as shown in the foregoing list. It is unquestionable that if Lahaina had not gone down with the various types of Lahaina disease, it would have been desirable to replace it because of its ready infection and severe injury from mosaic disease.

TABLE VIII

**The Susceptibility or Resistance of Lahaina to Diseases of These Islands**

| Name of disease | Causal agent | Susceptibility to infection | Degree of injury after infection |
|---|---|---|---|
| **Infectious** | | | |
| Mosaic disease | Apparently a filtrable virus | Severe | Severe |
| Eye spot | *Helminthosporium sacchari* | Severe | Moderate |
| Red stripe | *Phytomonas rubrilineans* | Unknown | |
| Iliau | *Gnomonia iliau* | Moderate | Moderate |
| Ring spot | *Leptosphaeria sacchari* | Susceptible | Negligible |
| Pineapple disease of standing cane | *Thielaviopsis sacchari* | Susceptible | Severe |

| | | |
|---|---|---|
| **Non-infectious** | | |
| Hamakua Lahaina disease | Unknown | Severe |
| Salt injury type of Lahaina disease | Excess salt content of soil solution | Severe |
| Pahala blight | Unknown | Severe |
| Sectional chlorosis | Unknown | Unknown |
| Freckle | Unknown | Slight |
| Limestone chlorosis | Unknown | Severe |
| Cane yellows type of chlorosis | Unknown | Moderate |

TABLE IX

**The Susceptibility or Resistance of the Hawaiian-grown Type of Uba to Foreign Cane Diseases**

| Name of disease | Causal agent | Susceptibility to infection | Degree of injury after infection |
|---|---|---|---|
| Fiji disease | Unknown | Slight | Moderate |
| Gumming disease | *Phytomonas vasculara* | Resistant | Resistant |
| Leaf scald | A bacterial organism undescribed as yet | Resistant | Resistant |
| Streak disease | Unknown | Susceptible | Estimated 10% loss of cane tonnage |
| Downy mildew | *Sclerospora sacchari* | Severe | Severe |
| Cane smut | *Ustilago sacchari* | Severe | Severe |
| Rust | *Puccinia kuehnii* | Resistant | Resistant |

It will be seen from the foregoing list that Uba, although highly resistant to one group of diseases such as gumming disease, leaf scald and Fiji disease, is extremely susceptible to cane smut and downy mildew. Since Uba is now being used extensively here as a parent in breeding new seedlings, it is highly important that such foreign diseases be excluded from these Islands.

TABLE X

**The Susceptibility or Resistance of the Hawaiian-grown Type of Uba to the Diseases of These Islands**

| Name of disease | Causal agent | Susceptibility to infection | Degree of injury after infection |
|---|---|---|---|
| **Infectious** | | | |
| Mosaic disease | Apparently a filtrable virus | Immune | |
| Eye spot | *Helminthosporium sacchari* | Resistant | Negligible |
| Red stripe | *Phytomonas rubrilineans* | Resistant | Negligible |
| Ring spot | *Leptosphaeria sacchari* | Susceptible | Negligible |
| Pineapple disease of standing cane | *Thielaviopsis sacchari* | Resistant | Negligible |

| | | |
|---|---|---|
| **Non-infectious** | | |
| Hamakua Lahaina disease | Unknown | Resistant |
| Salt injury type of Lahaina disease | Excess salt content of soil solution | Resistant |
| Pahala blight | Unknown | Resistant |
| Sectional chlorosis | Unknown | Not observed |
| Freckle | Unknown | Slight |
| Limestone chlorosis | Unknown | Not observed |
| Cane yellows type of chlorosis | Unknown | Resistant |

Uba cane is notably resistant to the various types of injuries which seem to arise from soil conditions. It would seem to be especially valuable as a parent in breeding towards resistance to such sort of injuries.

TABLE XI

**The Susceptibility or Resistance of Badila to Foreign Cane Diseases**

| Name of disease | Causal agent | Susceptibility to infection | Degree of injury after infection |
|---|---|---|---|
| Fiji disease | Unknown | Some degree of resistance | More tolerant than most varieties |
| Gumming disease | *Phytomonas sacchari* | Resistant | Resistant |
| Leaf scald | A bacterial organism undescribed as yet | Resistant | Resistant |
| Streak disease | Unknown | Susceptible | Unknown |
| Cane smut | *Ustilago sacchari* | Resistant | Resistant |
| Downy mildew | *Sclerospora sacchari* | Resistant | Resistant |
| Curly top | Unknown | Resistant | Resistant |
| Rust | *Puccinia kuehnii* | Resistant | Resistant |

From the foregoing list it can be seen that Badila is very resistant to a large number of infectious diseases; as a parent for breeding more productive seedlings, its desirability is self-evident.

TABLE XII

**The Susceptibility or Resistance of Badila to the Diseases of These Islands**

| Name of the disease | Susceptibility to infection | Degree of injury after infection |
|---|---|---|
| Mosaic disease | Resistant | Severe |
| Eye spot | Resistant | Resistant |
| Red stripe | Resistant | Resistant |
| Ring spot | Moderate | Negligible |
| Pineapple disease of standing cane | Not observed | |

Badila has not been observed under the conditions which develop many of the non-infectious diseases. It is known, however, to be resistant to Pahala blight.

The reaction to our diseases of some of the newly introduced Java canes may be of interest. P. O. J. 36, 213, 234 and 979 are all reputed to be readily susceptible to mosaic disease in the West Indies, but the statements are frequently made that the canes are tolerant of the disease and suffer very little loss following infection. There have been no figures available to us showing the degree of loss. Visual estimates of the degree of loss in the case of mosaic disease are of little value and it would be much more satisfactory to have the results from actual yields or at least from growth measurements in the case of these varieties.

These four Java varieties have been tested out in what we call our eye spot index tests. In these tests new varieties are tried out for eye spot susceptibility in comparison with H 109 and Yellow Caledonia. H 109 is given an empirical value of 1,000 to represent its susceptibility and Yellow Caledonia an empirical value of 0 to represent its resistance. In such tests P. O. J. 36 has an eye spot index close to 200; P. O. J. 213, 0; P. O. J. 234, almost 0; and 979 close to 100. It is safe to say that all four of these varieties are commercially resistant and can be grown in any district of these islands with no tangible losses from eye spot.

P. O. J. 36 and 234 have been reported to be affected by red-stripe disease.

Uba Hybrid No. 1 has an eye spot index of close to 500 and the losses from eye spot would be appreciable in districts favorable for eye spot infection such as Pahala, Naalehu, Waialua, etc.

W. W. G. Moir, of this committee, has some extensive observations on the eye spot susceptibility of the Hawaii 5,900 and 8,900 series, the Wailuku seedlings, the Manoa seedlings and Kohala seedlings. These observations are tabulated below in Table XIII:

TABLE XIII

Observations by W. W. G. Moir on the susceptibility or resistance to eye spot of the more promising seedlings of the H 5900 series, H 8900 series, the Wailuku series, Manoa series and Kohala seedlings.

| Series | Highly Resistant | Slightly Susceptible | Readily Susceptible | Severely Affected |
|---|---|---|---|---|
| H 5900 | H 5923 | **H 5909** | H 5922 | H 5908 |
| | **H 5978** | H 5940 | | H 5972 |
| | H 5965 | H 5964 | | |
| | | H 5974 | | |
| | | H 5949 | | |
| H 8900 | H 8907 | H 8918 | **H 8906** | H 8940 |
| | H 8938 | H 8929 | H 8901 | H 8947 |
| | H 8945 | H 8942 | H 8911 | H 8946 |
| | **H 8952** | H 8948 | H 8919 | H 8949 |
| | H 8961 | H 8954 | H 8920 | H 8968 |
| | | **H 8958** | H 8922 | H 8973 |
| | | **H 8969** | H 8928 | H 8983 |
| | | **H 8965** | H 8924 | H 8984 |
| | | H 8976 | H 8933 | H 8992 |

| | | | | |
|---|---|---|---|---|
| | | H 8982 | H 8935 | |
| | | **H 8988** | H 8956 | |
| | | **H 8994** | H 8978 | |
| | | | **H 89102** | |
| Wailuku series | W 2 | W 1 | **W 4** | W 3 |
| | | W 5 | W 6 | |
| | | W 9 | W 7 | |
| | | W 11 | W 8 | |
| | | **W 51** | W 10 | |
| | | W 63 | W 12 | |
| | | **W 73** | W 13 | |
| | | **W 71** | W 17 | |
| | | | W 48 | |
| | | | **W 50** | |
| | | | W 53 | |
| Manoa seedlings | 148 | 102 | 33 | |
| | 160 | | 60 | |
| | 185 | | 67 | |
| | 186 | | 77 | |
| | 187 | | | |
| | 188 | | | |
| | 209 | | | |
| | 213 | | | |
| | 198 | | | |
| Kohala seedlings | | K 107 | K 73 | |
| | | K 115 | K 117 | |
| | | K 202 | | |

In the foregoing table the varieties in heavy type are those which seem to have considerable value for commercial plantings. In this list H 109 would be considered as belonging in the last column, that is, under "Severely Affected."

To review the plantation situation in regard to cane diseases in relation to varieties and the propagation of new seedlings:

The most immediate need seems to be for a cane equal to the Tip canes in production and in economy of production for mauka conditions on unirrigated lands which will also be resistant to mosaic disease, red stripe, and eye spot; the Tip canes which now occupy these lands are very susceptible to mosaic and red stripe.

The next need, possibly an equally important need, is a variety for those districts where the climatic conditions favor eye spot; a variety is needed equal to H 109 in production, equally resistant or more resistant than H 109 to mosaic disease and resistant to eye spot. This is a rather large order to fill, but is not impossible.

With such varieties and with the maintenance of the Islands free from new foreign diseases, these Islands would be ideally protected from losses from cane diseases.

# Firing and Care of Locomotive Boilers*

By J. A. Good

The construction and upkeep of locomotive boilers have many features. One of the most essential is the correct application and care of tubes, and it is highly important that proper maintenance be given to securing the maximum results and minimum failures under operating conditions.

Tube troubles are the most general failures encountered in boilers and, where such exist, can very often be traced to mechanical causes, such as improper application or maintenance of tubes and to variation of temperature; yet many failures develop on account of inferior quality of tubes, which cannot at all times be detected on the surface or without an analysis or physical test.

The correct diagnosis of the causes is frequently the most important step in repair operations. Executives and employees who are responsible and interested in maintenance of locomotive boilers will find the study of these causes and the proper methods of making necessary repairs to be a very essential part of locomotive maintenance economy.

The firebox end is subjected to the most severe use and should be given the most careful attention so as to guard against hasty repairs which invariably give only a temporary relief and unnecessary delay and labor cost, and, sooner or later, result in taking the locomotive again out of service and doing the job right. In this regard, workmen should be instructed to take time to do work well from the first, as continual working on tubes has a very material effect in reducing not only the life of the tube ends but in some cases maltreating the tube sheet.

The use of roller or sectional expander on firebox end of tubes is largely a matter of local selection and the intelligence and skill of labor employed. Generally speaking, a roller expander should not be used by inexperienced men, who are very apt to over-roll excessively and reduce the tube gauge and in time injure the flue sheet. Preference in this case should be given to the ordinary type of sectional expander which is designed and most suitable to the tube size and sheet thickness. With the use of this type of expander, the chance of injury to tube or sheet is reduced to a minimum.

Leaky tubes also develop from vibration. This need not be considered of great importance as, under ordinary operating conditions, a properly set tube is well supported by the water surrounding it. The vibration encountered in the shipment of empty boilers can be the cause of loose tube ends; hence it is always advisable to lightly rework the tube ends of such boilers before placing them in service.

The abrasive action of cinders also causes "burnt off or cracked heads" and in turn develops leaky tubes. This is a condition well recognized by the railways throughout the world, using coal for fuel.

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

Variation in temperature is a daily occurrence with all boiler tubes. Tubes can be heated and cooled very often without becoming loose, providing all connected parts are heated and cooled uniformly, but trouble and leaky tubes are bound to develop where the variation in temperature is unequal and every effort should be exercised to guard against this condition.

Definite instructions should be made to prohibit the shutting off of oil fire and running or coasting of engine without the burner on, as the cold air drawn through tubes will result in injuring the firebox and tubes. A coal fire partly out will also prove harmful when running. Careful firing, especially with coal, to guard against the sudden and excessive admission of cold air into the firebox will prevent leaks to a great extent and prove very beneficial to the operation of the locomotives. Where oil is used as fuel, the admission of cold air is much less due to firedoor being closed.

Firemen should at all times make it a point to close the firedoor after each shovelful of coal is applied, the result of which is bound to reflect on the life and condition of tube ends, and also the boiler.

Unequal variation in the water temperature caused by injection of feed water is also an important cause of leaks and the correct location of boiler check is of prime importance. Boiler check should be conveniently located, but as far as possible from the firebox.

When the boiler is being fed with water, the fire should be kept up. Should the throttle be closed at this time, it is advisable to use the blower to assist in circulating the water in the boiler.

Many consider that the most prolific cause of leaking tubes is incrustation. This will, of course, vary with the quality of water supplied to the locomotive and the district in which the locomotive is operating. Its remedy is careful attention and blowing off and washing out the boiler. The washing out should be done with water under a pressure of not less than 150 pounds with the use of cleaning rods, the result of which will do much to remedy this condition and in turn allow the locomotive to steam properly and with less fuel used.

In extreme cases proper treatment of feed water to reduce its propensity for scale formation is also advisable. The proper treatment in this respect should and can be best determined by first having the water analyzed to find out if water treatment is necessary. With this information, one is in a position to decide on the proper treatment.

As a general and remunerative procedure, the care of tubes and boilers by regular inspection for mechanical defects, by blowing off, by proper and effective boiler washing, and intelligent firing will prove of the greatest economy in locomotive operation and boiler efficiency. It might be well to suggest keeping an accurate record and definite time to have boilers washed. In any event boilers should be blown down and washed out as often as water conditions require.

While on the subject of boiler efficiency and economy, it is not amiss to call attention to the firing of an oil-burning locomotive. Oil firing differs very materially from that of coal, and more careful attention is necessary in oil-burning locomotives than in coal burning ones to render the combustion economical.

To produce the most satisfactory results, firemen should give their work close attention and both the fireman and engineer should work together. The fireman should change his fire as often as the engineer changes the throttle or reverse lever. This possibly will appear to some as being not always possible with labor conditions in the Territory. Nevertheless, a good fireman, by following out this method of firing an oil-burning locomotive, and by being watchful and diligent, can minimize the oil consumption to a noticeable degree. In fact a fireman on an oil-burning locomotive can save or waste more fuel than he can on a coal burner.

The first essential in good oil firing is the regulation of the oil feed directly in proportion with the requirements of the work. If followed out, this will result in the consumption of a minimum quantity of oil.

Increase in firing should immediately precede the opening of the throttle and a reduction should follow the closing of throttle. The engineer should give the fireman advance notice as both enginemen should work in harmony.

Forcing the fire on an oil-burning locomotive is liable to injure the firebox sheets and tubes and should therefore be avoided. In the event of an emergency making it necessary to force the fire beyond a reasonable point, care should be taken to provide sufficient water on crown sheet to prevent damage.

The burning of oil has a tendency to deposit a gummy substance on the firebox end of tubes. This is very likely to take place even with no appearance of smoke, soot, and even with careful firing.

The tubes of oil-burning locomotives should be cleaned of soot when running by placing a small quantity of sand in a funnel, the end of which has been inserted through opening in firedoor. This cleaning should be done while the locomotive is working hard. With long stroke of valves and throttle wide open, this will allow the strong exhaust to draw the sand through the tubes, cutting the soot and gum from them in its passage and discharging it from the stack. It is better to use the sand frequently and in small quantities than to use large amounts only a few times.

To secure the maximum boiler results, clean tubes, both inside and out, are a big factor, and the boiler should be continually inspected to see that none of the tubes are stopped up. Should there be any stoppage, the use of an auger of sufficient length to reach from end to end should be followed by a careful inspection.

In view of the ease with which the extravagant use of fuel can be effected in burning oil, it appears highly advisable to exert every effort to properly handle the locomotive, the burner, and accessories in order to obtain economical combustion and to guard against injury to boiler or firebox.

# A Review of Our Present Fertilizer Practices Compared to Those of Ten Years or More Ago*

By J. A. Verret

We feel that considerable progress has been made in the use of fertilizer during the last ten years. The crop last year was slightly over 700,000 tons of sugar, the estimated crop this year is over 780,000 tons. These are the largest crops ever raised in the territory. These increases are not due so much to increased acreage as to increased yields per acre. The average yield will be over 6.5 tons of sugar per acre for 1925. The average sugar production for the last ten years was approximately 600,000 tons, about 5.00 tons of sugar per acre. The average acre yields for the years 1905-14, inclusive, were 4.87 tons sugar per acre.

The above figures show that during the last twenty years our acre yields have been gradually increasing.

These increased yields are due to a number of causes, such as, better mill recoveries, better varieties, especially H 109, as well as improvements in methods of cultivation. Good climatic conditions had a great deal to do with the splendid results obtained from the last two crops, but unless we are wide awake, we may not be able to take full advantage of good climatic conditions. We do not want it understood that we claim all these gains due to fertilization, but we do claim that a very appreciable part is due to a better understanding of the problems of fertilization.

## Amounts of Fertilizer Used, Past and Present

In 1914, we used 44,000 tons of fertilizer. In 1924, the sugar plantations used 95,000 tons. In 1914, the area in cane to be fertilized (1915 and 1916 crops) amounted to 214,346 acres, thus showing a fertilizer application of 410 lbs. per acre per year, or about 800 lbs. per acre per crop. The area in 1924 (1925 and 1926 crops) was 229,244 acres, showing a present application of 825 lbs. per acre per year, or about 1550 lbs. per acre per crop. We thus see that the amounts of fertilizer used per acre have about doubled in the last ten years.

## Present Quality of Our Fertilizers

Not only are we using much larger quantities of fertilizer than we did ten years ago, but we are also using more concentrated formulas. This is especially the case with nitrogen. The amounts of nitrogen used have more than doubled during the last ten years. This increase in the use of nitrogen was brought about as a result of field experiments by the Experiment Station, H. S. P. A.,

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on the various plantations, as well as by experiments and observations by the plantations themselves. The results of these tests almost always indicated large gains from the use of nitrogen. Such was not the case with phosphoric acid and potash. In a large number of cases, there is no response at all, and hardly ever is the response as great as from nitrogen.

This has led to a somewhat radical change in the formulas of our high grade fertilizers and to an increased use of soluble nitrogen fertilizers such as nitrate of soda and ammonium sulphate. We give below the average composition of the high grade fertilizers used from 1907 to 1915:

TABLE I

Average High Grade Formula

| Year | Nitrogen | Phos. Acid | Potash |
|---|---|---|---|
| 1907–08 | 6.33% | 7.54% | 10.53% |
| 1908–09 | 6.21 | 7.78 | 10.33 |
| 1909–10 | 7.10 | 7.39 | 9.07 |
| 1910–11 | 8.21 | 7.13 | 8.19 |
| 1911–12 | 8.37 | 7.17 | 7.80 |
| 1912–13 | 8.61 | 6.77 | 7.89 |
| 1913–14 | 8.57 | 6.60 | 8.32 |
| 1914–15 | 8.63 | 6.76 | 7.33 |
| 8-year average | 7.75 | 7.14 | 8.68 |

We give below some typical formulas used in the various districts at the present time:

No. 1.

12% N — 5% Ammonium Sulphate; 6% Nit. Potash; 1% Organic

5% $P_2O_5$ — 2% Superphosphate; 3% Bone Meal

10% $K_2O$ — 6% Nit. Potash; 4% Sulph. or Muriate Potash

No. 2.

11% N — 6% Nit. Potash; 4% Ammonium Sulphate; 1% Organic

6% $P_2O_5$ — 3% Superphosphate; 3% Bone Meal

6% $K_2O$ — Nit. Potash

No. 3.

9% N — 2½% Nit. Potash or Soda; 6% Ammonium Sulphate; ½% Organic

9% $P_2O_5$ — 4½% Superphosphate; 4½% Bone Meal

6% $K_2O$ — Nitrate or Sulph.

Formulas of the type shown by No. 1 above are used in districts of potash shortage, such as the Hilo district.

Formulas of the type shown by No. 3 are for districts of phosphoric acid shortage. This is generally the upper elevations on all Islands. Instead of using a high phosphoric acid high grade, such as No. 3, often extra application of phosphates are made at planting time and to young ratoons. This generally consists of 500 to 1000 lbs. per acre of superphosphate, reverted phosphate or raw rock phosphate.

Formulas of the type of No. 2 are used when no great shortage of either phosphoric acid or potash is indicated.

### Methods of Application

The tendency during recent years has been to apply the fertilizer in larger and fewer doses than was the case formerly. Sometimes as much as 1000 lbs. or more per acre of high grade are applied in one dose. Generally all the fertilizer for a two-year-crop is applied in three doses. Sometimes this is extended to four, and on some occasions, cut down to only two. Short ratoons get from 1 to 2 applications. Applying the fertilizer in fewer doses of course saves the extra cost of application; it also enables one to finish fertilizing at an earlier date, thus giving the cane an opportunity to mature before harvest, thereby giving better juices than would otherwise be the case.

Varying the number of applications (within reasonable limits, say, 3, 4 or 5 doses for long crops) in which a given amount of fertilizer is put on does not very materially affect the yield of cane.

### Forms of Nitrogen Used

As the result of a large number of field tests conducted on the plantations, it has been found that under practically all conditions the best returns per unit of nitrogen both in cost and quantity are obtained from the more soluble inorganic salts, such as nitrate of soda or ammonium sulphate, rather than from organic sources such as dried blood.

Very little organic fertilizer is now used. Most of that which is used is in the form of bone meal in the mixed fertilizer, where it is used mostly to improve the mechanical quality of the mixture and not on account of superior quality as a fertilizer.

Of the inorganic salts of nitrogen, tests show no great variation between them. In the warmer districts the returns are practically equal between nitrate of soda, nitrate of lime and ammonium sulphate. In the cooler districts the nitrates are more rapid in action and the yields as a whole are somewhat better than from ammonium sulphate. It would therefore seem to be advisable to use nitrate of soda or lime on the mauka lands of the plantations, even at a somewhat higher price per unit of nitrogen, in preference to ammonium sulphate. The fast work of nitrate nitrogen may also be an advantage in the dry dis-

tricts where it is important to take full advantage of optimum moisture conditions. On the warm, well irrigated plantations, these differences are not so important.

### Forms of Phosphoric Acid

Although the evidence is not as strong as in the case of nitrogen, the indications are very strong that in the majority of cases superphosphate will give better results than either reverted phosphate or raw rock phosphate, although in some instances raw rock has given unexpectedly good returns, particularly when costs are considered.

### Soil Surveys

The work of the chemistry department of the Experiment Station, H. S. P. A., has been of great value in the last years in helping develop our present fertilizer practices. There has been considerable difference of opinion in the past as to the value of soil analyses. More especially was this true in regard to drawing conclusions from them as to fertilizer requirements. It is now felt that there has been built up a fund of sufficient information from the work on the soils of the sugar plantations to justify us in certain general conclusions as to the probable fertilizer response of the soils in various districts. This work was based upon the detailed study of the soils of field experiments carried on by the Agricultural department of the Experiment Station, H. S. P. A.

The work that was done on these various soils indicates that the amounts of the soil minerals soluble in 1 per cent citric acid solution are a valuable indication of the availability of the plant food in the soil.

The results tend to show that the soils which fail to give a response to phosphate fertilization are those which are not only high in citric acid soluble phosphates, but also have a good content of citric acid soluble, lime and silica. By a good supply of citric acid soluble phosphates we mean percentages of $P_2O_5$ greater than .004 per cent. This should be accompanied by approximately 0.15 per cent of soluble lime and silica. When these conditions occur, we feel very certain that there will be no response to phosphate fertilization.

The exact figures may be somewhat modified by later work, but we only consider that amounts notably less than these figures definitely indicate a phosphate shortage. In the samples from the phosphate experiments, there was a response to phosphate fertilization in practically every case where there was 0.0025 per cent or less of citric acid soluble phosphate, and a low content of soluble lime and silica.

Soils with a soluble phosphate content between these high and low figures vary in their response and require field tests to be certain. In such cases, as a matter of insurance to keep up soil fertility, the Experiment Station is inclined to recommend the use of some phosphate, unless financial conditions are such that strict economy is demanded for the time being.

The work with regard to potash would tend to show that a response is to be expected from soils with a citric acid soluble potash content below 0.025 per

cent when accompanied by low available lime. Soils with a citric acid soluble potash content above 0.03 per cent, with a fair amount of lime, generally do not respond to potash fertilization.

This work by the chemistry department has been of great value in enabling us to obtain very accurate ideas as to the fertilizer requirements of our various soils with very many less field tests than was formally the case. We also quote from Mr. Stewart as follows:

A low content of total potash or phosphates, accompanied by low, strong acid soluble, and low citric and soluble plant food, is much more certain to indicate a fertilizer response from potash or phosphates than is likely to be the case if the available plant food alone is low.

The percentage of acid soluble plant food is considered to be an indication of the degree of weathering and future solubility of the soil minerals. We ordinarily expect to find at least 0.2 per cent of hydrochloric acid soluble phosphates. The content of total phosphates should range from 0.35 to 1.00 per cent, depending upon the district in the Islands from which the sample was taken. The hydrochloric acid soluble potash is usually about 0.2 per cent or more. The total potash ranges from 0.3 per cent to 1.0 per cent. There is ordinarily about 0.25 per cent or more of hydrochloric acid soluble lime.

In these soil surveys the greatest variations were found on Kauai, especially on the plantations from Koloa to Kilauea. In this district the mauka fields are generally very poor, not only in phosphoric acid, but in potash and lime. On the other hand, some of the lower fields show up extremely well.

In the Hamakua district the physical aspects seem to play a larger part. The depth of soil, water-holding capacity, grade and exposure all exert a big part. On account of some or all of these characteristics, some fields are very poor, although the soil shows up well in plant foods.

## The Effect of Nitrogen on the Quality of Cane Juices

The effect of nitrogen on cane juices is very important, so we present here some preliminary data bearing on the subject. Through lack of time, we were not able to finish the study we had undertaken. The data presented here extends to the year 1922 only. During next year we hope to finish up to date, always assuming that we have no labor troubles and that the plantations do not take away all the assistant agriculturists as they came very near doing this year.

The tables presented herewith are based on sixty-five nitrogen experiments and are intended to show the general effect on the juices as the amount of nitrogen used is increased.

### Average Quality Ratios by Island

Pounds of Nitrogen per Acre

| Location | 51 to 100 | 100 to 150 | 151 to 200 | 201 to 250 | 251 and Over |
|---|---|---|---|---|---|
| Hawaii .... | 7.66 | 7.72 | 7.86 | 8.02 | 8.12 |
| Kauai ..... | 8.45 | 8.63 | 8.77 | 8.80 | 8.98 |
| Maui ..... | 6.92 | 6.93 | 7.07 | 7.21 | 7.33 |
| Oahu ..... | 8.09 | 8.34 | 8.40 | 8 49 | 8.77 |
| Average ... | 7.78 | 7.90 | 8.02 | 8.13 | 8.30 |

From the above table we find that, for amounts between 50 and 250 lbs. of nitrogen per acre, increasing the nitrogen 50 lbs. per acre, within these limits, increases the quality ratio slightly more than 0.1 ton of cane. That is, an increase of 50 lbs. of nitrogen requires about 0.12 ton of cane more to make a ton of sugar.

In order to express the above variations more clearly to some, the above table was worked out on a percentage basis using 151 to 200 lbs. of nitrogen per acre as normal.

PER CENT VARIATION IN QUALITY RATIO FOR VARYING AMOUNTS OF NITROGEN

Pounds of Nitrogen per Acre

| Location | 51 to 100 | 100 to 150 | 151 to 200 | 201 to 250 | 251 and Over |
|---|---|---|---|---|---|
| Hawaii ..... | 97.5% | 98.3% | 100.0% | 102.1% | 103.3% |
| Kauai ..... | 96.4 | 98.4 | 100.0 | 101.4 | 102.4 |
| Maui ..... | 97.9 | 98.0 | 100.0 | 101.9 | 103.7 |
| Oahu ..... | 96.4 | 99.3 | 100.0 | 101.0 | 104.4 |
| Average ... | 97.0 | 98.5 | 100.0 | 101.6 | 103.5 |

The above table may be used to calculate the quality ratios which we might expect were we to increase or decrease the nitrogen used, other factors remaining the same. Such a calculation was made, using the 1924 quality ratios for the Islands as given in the Annual Synopsis of Mill Data. It was assumed that we are now using from 151 to 200 lbs. of nitrogen per acre. The actual 1924 quality ratios are in the nitrogen column headed by these amounts. The figures in the other columns are the quality ratios which might be expected from the changed nitrogen.

POUNDS OF NITROGEN PER ACRE

| Location | 51 to 100 | 101 to 150 | 151 to 200 | 201 to 250 | 251 and Over |
|---|---|---|---|---|---|
| Hawaii .... | 8.64 | 8.71 | 8.86 | 9.05 | 9.15 |
| Kauai ..... | 7.83 | 7.99 | 8.12 | 8.23 | 8.31 |
| Maui ..... | 7.42 | 7.43 | 7.58 | 7.66 | 7.86 |
| Oahu ..... | 7.87 | 8.10 | 8.16 | 8.24 | 8.52 |
| Average ... | 8.00 | 8.13 | 8.25 | 8.38 | 8.54 |

## SUMMARY OF THE RESULTS OF FIELD TESTS

### LIME

For a number of years we have been conducting field experiments to determine the value of liming on the fields of the various sugar plantations. In this article we propose to give a summary of our results to date.

Some confusion exists in the popular mind with reference to the nature of lime and its use. Before proceeding with our summary, it may be well to discuss these points briefly.

When the chemist speaks of "lime" he refers to calcium oxide (quicklime) only, but when we refer to lime in the agricultural sense we include three different materials: burned or quicklime (calcium oxide), hydrated or water-slaked lime (calcium hydrate), and ground limestone or air-slaked lime (calcium carbonate). Gypsum, or calcium sulphate, is not included in the term "lime," although it contains calcium.

These materials contain various amounts of calcium as indicated. That is: 56 lbs. of quicklime equal 74 lbs. of hydrated or water-slaked lime or 100 lbs. of ground limestone. The other way about, 100 lbs. of quicklime equal 132 lbs. of water-slaked lime or 179 lbs. of ground limestone. With these figures in mind, one may figure the relative costs. When either quicklime or hydrated lime is exposed to the air, they gradually absorb carbon dioxide and tend to change to lime carbonate, or limestone.

The function of lime in soils is given briefly as follows:

1. Lime materials serve as a source of the element calcium to plants. Calcium is one of the essential elements in plant growth. As a rule most of our soils are pretty well supplied with calcium; besides this, we apply fairly large amounts of it in the phosphates which we use in our mixed fertilizer and directly.

2. Lime materials have the power of shrinking clay and making it more pervious to water and air. Lime, therefore, makes clays and adobe soils looser, and improves the mechanical condition of this type of soils.

3. Lime materials (when used in proper amounts) make "sour" soils "sweet", changing an acid condition into a neutral or slightly alkaline one. This is essential to many crops, but our tests indicate that sugar cane is very tolerant to sour conditions, although our best yields are obtained from neutral or slightly alkaline soils.

4. Lime materials are necessary for the beneficial bacteria and other microorganisms of the soil.

5. Lime materials promote the normal decay of organic matter in the soil.

6. Lime materials, under some conditions, make soluble some of the insoluble forms of the more valuable plant foods such as potash and the phosphates.

7. Lime materials, when added to nearly or complete neutrality, precipitate soluble alumina.

For the purpose of loosening heavy soils mentioned in (2) burned or hydrated lime is to be preferred when prices allow. It acts more quickly. Lime is best applied before plowing, several months before planting, particularly if quick or hydrated lime is used. On the sour, lighter, sandy or loam soils, ground limestone is to be preferred to either of the other two.

In the following table the results of our lime tests are given briefly and the results summarized:

## Lime Experiments

| | Plantation | | Crop Year | Lime Cane | Lime Sugar | No Lime Cane | No Lime Sugar |
|---|---|---|---|---|---|---|---|
| 1. | Waipio Substation ..... 0 | | 1916 | 80.4 | 11.15 | 80.1 | 10.85 |
| 2. | " " ..... 0 | (Residual) | 1918 | 88.0 | 9.87 | 84.1 | 9.29 |
| 3. | " " ..... 0 | (Residual) | 1920 | 66.1 | 8.37 | 64.2 | 8.34 |
| 4. | Wailuku Sugar Co..... 1 | | 1917 | 86.4 | 12.40 | 81.2 | 12.18 |
| 5. | " " " ..... 1 | (Residual) | 1919 | 74.1 | 10.87 | 71.2 | 10.68 |
| 6. | Kilauea Sugar Plan. Co..... 4 | | 1917 | 27.2 | 3.09 | 25.5 | 2.94 |
| 7. | " " " " ..... 7 | | 1918 | 31.9 | 3.73 | 31.5 | 3.69 |
| 8. | Oahu Sugar Co..... 8 | | 1918 | 67.8 | 7.25 | 65.6 | 7.18 |
| 9. | Hilo Sugar Co.....18 | | 1921 | 47.3 | 5.91 | 45.2 | 5.65 |
| 10. | " " " .....18 | (Residual) | 1923 | 58 9 | 6.65 | 56.8 | 6.31 |
| 11. | Hawi Mill & Plant. Co..... 2 | | 1919 | 54.0 | 6.86 | 52.3 | 6.59 |
| 12. | Paauhau Sugar Plan. Co.....10 | | 1919 | 46.7 | 5.62 | 45.6 | 5.57 |
| 13. | Niulii Mill & Plan. Co..... 1 | | 1922 | 16.7 | 1.92 | 15.2 | 5.97 |
| 14. | Kaiwiki Sugar Co..... 1 | | 1917 | 42.1 | 5.65 | 40.9 | 5.67 |
| 15. | Hamakua Mill Co..... 1 | | 1918 | 15.3 | 1.93 | 15.2 | 1.96 |
| 16. | " " " ..... 1 | (Residual) | 1920 | 26.7 | 3.53 | 26.5 | 3.52 |
| 17. | " " " ..... 2 | | 1918 | 11.2 | 1.34 | 11.0 | 1.34 |
| 18. | " " " ..... 2 | (Residual | 1920 | 20.8 | 2.63 | 19.6 | 2.43 |
| 19. | Oahu Sugar Co.....17 | | 1918 | 67.3 | 6.03 | 67.6 | 6.11 |
| 20. | " " " .....17 | (Residual) | 1920 | 96.6 | 13.70 | 101.6 | 13.68 |
| 21. | Grove Farm Co., Ltd..... 8 | | 1920 | 40.7 | 4.83 | 41.9 | 4.98 |
| 22. | " " " " ..... 8 | (Residual) | 1922 | 34 8 | 4.16 | 35.5 | 4.18 |
| 23. | Kaiwiki Sugar Co..... 4 | | 1922 | 24.5 | 3.21 | 24.6 | 3.39 |
| 24. | " " " ..... 4 | (Residual) | 1924 | 36.2 | 4.60 | 34.6 | 4.33 |
| 25. | Pepeekeo Sugar Co..... 5 | | 1922 | 49.7 | 6.45 | 51.7 | 6.52 |
| | Average ..... | | | 48.5 | 6.07 | 47.6 | 5.97 |
| | Average Quality Ratio..... | | Lime....7.99 | | | No Lime....7.97 | |

Since 1916, we have conducted a total of twenty-five lime experiments. These were on all the Islands and covered our various soil types.

In looking over the summary we find that in thirteen of the twenty-five some gains were obtained; in twelve there were no gains from the lime. In practically no case were the gains especially large or significant.

The cane plant would seem to tolerate very wide fluctuations in the lime reaction of a soil. We find very good crops being produced on lands which are almost pure coral; good crops are also produced on soils which are extremely acid, requiring 10 to 12 tons of lime to bring to neutrality. This shows that with us the lime problem is not an especially vital one.

The conditions under which liming would be most likely to give the best returns are on the acid mauka soils which respond to phosphoric acid. Liming such soils would improve conditions for the phosphates and likely tend to an economy in their use.

The average quality ratio of the juices from lime plots was 7.99, while that from the no lime plots was 7.97. We thus see that lime had no effect whatever on the quality of the juices.

## The Effects of Phosphoric Acid and Potash on Cane Juices

During recent years the average quality of cane juices on the different islands has shown a downward tendency. The question has been raised as to whether our systems of fertilizing were in any way responsible for this. With this in mind we have recently made a rather careful review of all our fertilizer experiments and compared the juices from the plots receiving different fertilizer treatments. In this paper we are reporting the results of this study in regard to the effect of phosphoric acid and potash.

## The Action of Phosphorus and Potassium on Plants

Before going into the details of the results of our experiments here, we shall give briefly the effects produced on crops by these two elements as given in the literature. These general conclusions given by the different authors are based almost entirely upon temperate zone plants, mainly cereals.

Phosphoric acid is very beneficial in favoring the rapid development of young plants by stimulating the growth of roots. This points to the importance of the early application of phosphates.

Protoplasm cannot exist without phosphorus, and as there can be no plant growth without protoplasm this is very important.

Phosphates are reported to favor the early ripening of crops. The formation of grain is hastened by the free application of phosphates. This maturing effect of the phosphates is due to this hastening of seed formation. Phosphorus is always found more abundantly in the seed than in other parts of the plant. In non-seed crops this maturing effect may not be evident.

Potassium compounds are necessary in order that a plant may produce starch, sugar, cellulose and other carbohydrates. Potassium seems to be necessary for transference of starch from the leaves to other parts of the plant. Potash plays a large part in the development of leaves and the woody parts of the stems of plants. Larger portions of potash are found in these parts of plants. Large amounts of potash tend to prolong the life of plants, thereby delaying maturity, and thus having an effect directly opposite to that of phosphoric acid. Here we have an indication of the importance of early application of potash compounds in order that the potash needed may be used as early as possible and give time for the plant to mature. Potassium compounds give the plant more resistance to the attacks of fungous diseases, such as rusts, especially. Crops not receiving enough potash seem to be more susceptible to diseases of all kinds.

## Experimental Results

The results herein reported are based on a total of 118 experiments, covering all the Islands and extending from 1917 to 1925.

Each experiment consisted of from 5 to 12 repetitions of each treatment. In nearly all cases, all plots were sampled, and the juices averaged for each treatment. The figures given are the averages of several hundred juice analyses, com-

posed of over a thousand samples, and it would therefore seem that the results obtained can be accepted as more or less conclusive.

The results show no effect whatever on the quality ratio of juices from the use or omission of either phosphoric acid or potash or both. This statement has no reference to the effect of phosphoric acid on the clarifying properties of a cane juice. Recent work by Walker, of Pioneer Mill Company, and McAllep, of this Station, points to the fact that the phosphoric acid content of a cane juice has a very important bearing in factory work. When below a certain minimum of phosphoric acid, juices clarify rather poorly. What that minimum is, or what its relation is to the phosphoric acid content of the soil, is not yet clearly established, as some obscure points remain to be worked out. For instance, the juice from certain fields may be rather low in $P_2O_5$ and not clarify very well, yet the cane fails to respond to phosphate applications.

Below we give in tabular form a summary of the results obtained from the different treatments:

### Phosphoric Acid

| | Quality Ratio of Juice | |
|---|---|---|
| | Phos. Acid | No Phos. Acid |
| Average of all experiments responding to phosphates..... | 8.31 | 8.29 |
| Average of all experiments not responding to phosphates.... | 8.55 | 8.49 |
| Average of all..... | 8.44 | 8.39 |

### Potash

| | Quality of Juices | |
|---|---|---|
| | Potash | No Potash |
| Average of all experiments responding to potash applications..... | 8.27 | 8.26 |
| Average of all experiments not responding to potash applications.... | 8.24 | 8.17 |
| Average of all..... | 8.25 | 8.22 |

### Phosphoric Acid and Potash

| | Quality of Juices | |
|---|---|---|
| | Phos. Acid and Potash | No Phos. Acid and Potash |
| Average of all experiments responding to phosphoric acid and potash..... | 8 24 | 8.18 |
| Average of all experiments not responding to phosphoric acid and potash..... | 7.36 | 7.30 |
| Average of all..... | 7.92 | 7.86 |

The above results show that in arriving at the cause of our poorer juices we must look elsewhere than to the presence or absence of phosphoric acid or of potash in our fertilizers. We have previously shown what effect nitrogen has.

Some of these causes may be adverse climatic conditions, change of cane varieties, late harvesting, late fertilizing, increased nitrogen applications, increased yield of cane per acre, or age of cane when harvested.

Some of the above factors we can control, others we cannot. When Lahaina refuses to grow we must change to another variety of cane, even though the juices be poorer. We cannot do much with climate, but we can fertilize earlier.

With our present labor conditions, late harvesting is to be expected. Beginning in July, cane juices go back very fast. But this "going back" seems to is, cane 24 to 30 months old seems to deteriorate much more than is the case with apply to old cane to a much greater degree than it does to younger cane—that cane 15 to 18 months old. Our best juices last year at Waipio were from short ratoons harvested in late August. We do not believe that these short ratoons had deteriorated at all when harvested.

We feel that this question of short ratooning is a very important field for more extensive experimentations on the plantations.

We would suggest the trial of short ratooning to the extent that all cane ground from July on be short ratoons.

There is a possibility that the sugar made from this younger cane late in the year would have a better refining value than sugar made from older, deteriorated cane. Deterioration of cane is accompanied by more or less gum formation, and this, in turn, has a direct bearing on the filtering quality of the sugar.

### Quality of Juices in Potash Experiments

| Experiments | Quality Ratio of Juice Potash | No Potash | Gain from Potash |
|---|---|---|---|
| HAWAII | | | |
| Hakalau 13, 1923, Field H8 | 8.64 | 8.22 | Yes |
| Hakalau 13, 1925 | 8.66 | 8.57 | Yes |
| Hamakua 5, 1922 | 7.74 | 7.30 | No |
| Honokaa Obs. B, 1921 | 7.40 | 7.65 | Yes |
| Onomea 6, 1918 | 8.42 | 8.27 | Yes |
| Onomea 6, 1920 | 8.64 | 8.58 | Yes |
| Onomea 6, 1922 | 7.95 | 7.77 | Yes |
| Onomea 8, 1919 | 7.61 | 8.11 | Yes |
| Onomea 8, 1921 | 7.67 | 8.56 | Yes |
| Onomea 8, 1923, Field 25 | 8.20 | 8.49 | Yes |
| Onomea 9, 1919 | 7.62 | 7.91 | Yes |
| Onomea 9, 1921 | 7.32 | 7.27 | Yes |
| Onomea 11, 1922 | 7.71 | 7.25 | Yes |
| Pepeekeo 6, 1922 | 8.05 | 7.88 | Yes |
| KAUAI | | | |
| Kilauea 23, 1920 | 9.58 | 9.94 | Yes |
| Kilauea 24, 1920 | 9.73 | 9.73 | Slight |
| Kilauea 25, 1921 | 8.30 | 8.29 | Slight |
| Kilauea 31, 1922 | 9 58 | 9.55 | No |
| Kilauea 31, 1924, Field 37 | 8.96 | 8.85 | Slight |
| Koloa 5, Field 5 | 9.04 | 8.83 | Yes |
| Lihue 2, 1921 | 8.81 | 8.78 | No |
| Lihue 7, 1922 | 7.65 | 7.76 | No |
| Makee Sugar 3, Field 13 | 8.27 | 8.30 | Yes |
| McBryde 2, 1919 | 7.53 | 7.43 | No |
| McBryde 2, 1921 | 7.24 | 7.41 | No |

| | | | |
|---|---|---|---|
| **MAUI** | | | |
| H. C. & S. Co 7, 1921 | 6.78 | 6.80 | No |
| M. A. Co. 8, 1921 | 8.85 | 8.90 | No |
| Pioneer 4, 1921 | 6.70 | 6.73 | Slight |
| **OAHU** | | | |
| Oahu Sugar Co. 4, 1920 | 7.41 | 7.46 | No |
| Oahu Sugar Co. 8, 1922 | 8.60 | 8.64 | No |
| Oahu Sugar Co. 14, 1920 | 7.13 | 6.89 | No |
| Waipio V, 1917 | 9.00 | 9.11 | No |
| Waipio V, 1918 | 9.37 | 9.12 | No |
| Waipio V, 1919 | 8.68 | 8.29 | No |
| Waipio V, 1921 | 9.13 | 9.13 | No |
| **AVERAGE** | | | |
| Average of all experiments | 8.25 | 8.22 | |
| Responding to potash | 8.27 | 8.26 | |
| Not responding to potash | 8.24 | 8.17 | |

## Quality of Juices in Phosphoric Acid Experiments

| Experiments | Quality Ratio of Juices Phosphoric Acid | No Phosphoric Acid | Gain from Phos. Acid |
|---|---|---|---|
| **HAWAII** | | | |
| Hakalau 4, 1919 | 8.12 | 8.19 | No |
| Hakalau 7, 1919 | 7.58 | 7.67 | No |
| H. M. Co. 3, 1922 | 7.24 | 7.27 | Yes |
| H. M. Co. 5, 1922 | 7.58 | 7.47 | No |
| H. A. Co. 2, 1922 | 8 26 | 8.29 | Yes |
| Honomu 1, 1919 | 8.73 | 8.57 | No |
| Onomea 9, 1919 | 7.55 | 7.81 | No |
| Onomea 9, 1921 | 7.40 | 7.19 | No |
| Paauhau 12, 1919 | 8.02 | 8.01 | Slight |
| Paauhau 12, 1921 | 9.43 | 9.48 | Yes |
| Paauhau 17, 1923 | 10.65 | 10.37 | No |
| Pepeekeo 1, 1917 | 7.08 | 7.02 | No |
| **KAUAI** | | | |
| Grove Farm 6, 1919 | 8 11 | 7.95 | No |
| Grove Farm 9, 1922 | 7.92 | 8.33 | Yes |
| Kilauea 5, 1917 | 9.50 | 9.38 | No |
| Kilauea 7, 1918 | 8.58 | 8.54 | No |
| Kilauea 17, 1920 | 9.71 | 9.62 | No |
| Kilauea 17, 1922 | 11.40 | 11.12 | No |
| Kilauea 27, 1921 | 9.40 | 9.20 | Yes |
| Kilauea 29, 1922 | 8.26 | 8.29 | Yes |
| Kilauea 30, 1922 | 8.19 | 7.76 | Yes |
| Kilauea 30, 1924, Field 37 | 8.44 | 8.24 | Yes |
| Kilauea 34, 1921 | 8.68 | 9.04 | Yes |
| Kilauea 35, 1921 | 8.87 | 8.92 | Yes |
| Lihue 1, 1921 | 8.91 | 8.71 | No |
| Lihue 2, 1921 | 8.80 | 8.92 | No |

| | | | |
|---|---|---|---|
| Lihue 6, 1922 | 8.40 | 8.00 | Yes |
| Lihue 7, 1922 | 7.70 | 7.80 | Yes |
| McBryde 2, 1919 | 7.48 | 7.42 | No |
| McBryde 2, 1921 | 7.51 | 7.23 | No |
| **MAUI** | | | |
| H. C. & S. Co. 7, 1921 | 6.76 | 6.79 | Yes |
| M. A. Co. 8, 1921 | 8.99 | 8.71 | No |
| Pioneer 3, 1921 | 7.27 | 7.18 | No |
| Pioneer 4, 1921 | 6.71 | 6.71 | Slight |
| **OAHU** | | | |
| Oahu Sugar Co. 4, 1922 | 8.95 | 8.72 | Yes |
| Oahu Sugar Co. 6, 1918 | 9.50 | 9.53 | Yes |
| Oahu Sugar Co. 6, 1920 | 7.02 | 7.02 | Yes |
| Oahu Sugar Co. 6, 1922 | 8.24 | 8.66 | Yes |
| Oahu Sugar Co. 14, 1920 | 7.11 | 7.11 | Yes |
| Waipio V, 1917 | 8.94 | 8.89 | No |
| Waipio V, 1918 | 9.29 | 9.46 | No |
| Waipio V, 1919 | 8.53 | 8.54 | No |
| Waipio V, 1921 | 9.15 | 9.15 | No |
| Averages | 8.44 | 8.39 | |
| Averages of experiments which responded to Phosphoric Acid | 8.31 | 8.29 | |
| Averages of experiments which did not respond to Phosphoric Acid | 8.55 | 8.49 | |

## Quality of Juices in Plant Food Experiments

| Experiments | Quality Ratio of Juice: Nitrogen Phos. Acid and Potash | Nitrogen Only | Gain from Phos. Acid and/or Potash |
|---|---|---|---|
| **HAWAII** | | | |
| Hamakua 5, 1922 | 7.78 | 7.23 | No |
| Halawa 3, 1924 | 7.46 | 7.58 | Slight |
| Honokaa 10B, 1924, Field 19 | 8.69 | 8.01 | No |
| Niulii M. and P. 2, 1924, Field 8 | 7.87 | 7.89 | Slight |
| Onomea 9, 1919 | 7.77 | 8.14 | Yes |
| Onomea 9, 1921 | 7.34 | 7.08 | Yes |
| Union Mill Co. 2, 1924, Field 94 | 7.65 | 7.66 | Slight |
| **KAUAI** | | | |
| Koloa 9, 1924, Field 20 | 9.67 | 10.16 | Yes |
| Koloa 11, 1924, Field 7 | 7.12 | 7.65 | Slight |
| Koloa 14, 1925, Field 51 | 8.92 | 8.65 | Slight |
| Lihue 2, 1921 | 8.92 | 8.78 | No |
| Lihue 2, 1923, Field 1 | 8.61 | 8.49 | Yes |
| Lihue 7, 1924, Field 13 | 8.68 | 8.24 | No |
| Lihue 7, 1922 | 7.80 | 7.80 | No |
| McBryde 2, 1919 | 7.53 | 7.42 | No |

| | | | |
|---|---|---|---|
| **MAUI** | | | |
| H. C. & S. Co. 7, 1921 | 6.76 | 6.80 | No |
| M. A. Co. 8, 1921 | 8.71 | 8.98 | No |
| Pioneer 4, 1921 | 6.71 | 6.73 | Yes |
| Pioneer 4, 1923, Field 1 | 8.61 | 8.49 | Yes |
| Pioneer 4, 1925, Field B6L | 6.90 | 6.80 | Yes |
| Pioneer 7, 1924, Field B2 | 7.53 | 7.53 | Yes |
| Pioneer 8, 1924, Field 31 | 7.00 | 6.79 | Slight |
| Pioneer 11, 1924, Field 4 | 8.66 | 8.65 | No |
| Pioneer 13, 1925, Field B-4 | 6.40 | 6.20 | Slight |
| Pioneer 17, 1925, Field 32 | 7.37 | 7.41 | No |
| Pioneer 20, 1925, Field L. A. 7 | 7.50 | 6.96 | No |
| Pioneer 22, 1925, Field G-2 | 6.40 | 6.40 | Yes |
| Pioneer 26, 1925, Field C-8 | 8.38 | 8.50 | Slight |
| Wailuku 11, 1923, Field 37 | 8.18 | 8.04 | Slight |
| Wailuku 12, 1923, Field 17 | 7.44 | 7.31 | Slight |
| Wailuku 13, 1923, Field 70 | 8.46 | 8.51 | Slight |
| Wailuku 14, 1923, Field 19 | 7.93 | 7.94 | No |
| Wailuku 15, 1923, Field 100 | 8.38 | 8.45 | Yes |
| **OAHU** | | | |
| Oahu Sugar 4, 1920 | 7.88 | 7.56 | Yes |
| Oahu Sugar 14, 1920 | 7.11 | 7.00 | Yes |
| Waipio V, 1917 | 9.59 | 9.53 | No |
| Waipio V, 1918 | 9.41 | 9.54 | No |
| Waipio V, 1919 | 8.06 | 7.90 | No |
| Waipio V, 1921 | 9.15 | 9.15 | No |
| Waipio V, 1923, Sec. 36 | 8.36 | 8.44 | Slight |
| Waipio LI, 1925 | 8.44 | 8.44 | No |
| Averages | 7.98 | 7.92 | |
| Average of experiments which responded | 7.76 | 7.75 | |
| Average of experiments which did not respond | 8.29 | 8.16 | |

# Hawaiian Factory Data*

By G. H. W. Barnhart

One interesting phase of a comparison of data covering the different factories in Hawaii is the great variety in size and arrangement of equipment, which, to all intents and purposes, is thoroughly standardized. There are nine distinct lengths of mill rollers ranging from 42 inches, at Waimea, to 84 inches, at McBryde, these mills being not more than six miles from each other. Hawaii has one two-roller crusher and six-roller mill at Halawa. There are seventeen nine-roller mills, eleven preceded by two-roller crushers, four by three-roller crushers and two by no crusher at all. Of twenty twelve-roller mills (two factories having two tandems each), seventeen are preceded by two-roller crushers,

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one by a three-roller crusher and two by no crusher at all. There are two fifteen-roller tandems, each preceded by a two-roller crusher, and two eighteen-roller tandems, one preceded by a two-roller, the other by a three-roller crusher. The predominance of the twelve-roller tandem, with two-roller crusher, indicates it as standard equipment. Thirty-six of forty factories use crushers, seven of these being three-roller crushers, which are popular because the installation is identical with a three-roller mill except for the coarser grooving and because of a somewhat better extraction. Twenty-nine factories report the use of knives, eight of them having double sets. There are fourteen Searby Shredder installations, while one old National is still doing service.

Practically every size of engine offered by manufacturers is to be found, the predominating makes being the Putnam, Edward Wood, Hamilton Corliss and Nordberg. The possible indicated horse power (I. H. P.) developed in each factory has been found by calculation, using the size, speed and initial and final pressures reported and a mean effective pressure (M. E. P.) corresponding to .40 cut-off. It will be noted that this I. H. P. capacity per T. C. H. varies from 10.1 at Halawa to 39.8 at Olowalu. Observations indicate that for a fairly uniformly loaded mill train the power required varies as the number of mills in the train—being 30 I. H. P. per T. F. H. for three-roller crushers and three-roller mills and 15 I. H. P. for two-roller crushers. Assuming an average fibre of 12½ per cent these figures become 3.75 and 1.875 I. H. P. respectively per T. C. H. and the power requirements for different mill arrangements are:

| Arrangement | I. H. P. | Arrangement | I. H. P. |
|---|---|---|---|
| 6 RM and 2 RC | 9.875 | 12 RM and 2 RC | 16.875 |
| 9 RM | 11.250 | 12 RM and 3 RC | 18.750 |
| 9 RM and 2 RC | 12.625 | 15 RM and 2 RC | 20.625 |
| 9 RM and 3 RC | 15.000 | 18 RM and 2 RC | 24.375 |
| 12 RM | 15.000 | 18 RM and 3 RC | 26.250 |

A comparison of the available with that required indicates five factories to be underpowered. A few have sufficient power and many have quite an excess, notably Honomu, with 245 per cent, and Olowalu, with 265 per cent, of requirements. In these calculations 0.40 cut-off was taken arbitrarily as this is about the limit for the Corliss valve. The results therefore indicate the normal maximum power available. That many installations are overpowered is of an advantage, as this permits cut-off nearer the point which will insure a minimum steam consumption.

To assist in determining the average capacity of a cane mill for Hawaiian conditions the table below is given. All mills in this class are preceded by revolving knives and a crusher:

| Size of mill and Number of rollers | Tons fibre hour | Tons cane per hour at fibre of 10% | 11% | 12% | 13% | 14% | 15% |
|---|---|---|---|---|---|---|---|
| 26 x 42 9 RM | 1.82 | 18.2 | 16.6 | 15.2 | 14.0 | 13.0 | 12.1 |
| 26 x 42 12 | 2.24 | 22.4 | 20.4 | 18.7 | 17.2 | 16.0 | 14.9 |
| 26 x 54 9 | 2.52 | 25.2 | 22.9 | 21.0 | 19.4 | 18.0 | 16.8 |
| 26 x 54 12 | 2.94 | 29.4 | 26.7 | 24.5 | 22.6 | 21.0 | 19.6 |
| 30 x 60 9 | 3.78 | 37.8 | 34.4 | 31.5 | 29.1 | 27.0 | 25.1 |
| 30 x 60 12 | 4.33 | 43.3 | 39.4 | 36.1 | 33.3 | 31.0 | 28.9 |
| 32 x 60 9 | 4.06 | 40.6 | 36.9 | 33.8 | 31.2 | 29.0 | 27.1 |
| 32 x 60 12 | 4.76 | 47.6 | 43.3 | 39.6 | 36.7 | 34.0 | 31.7 |
| 32 x 60 15 | 5.32 | 53.2 | 48.4 | 44.2 | 40.9 | 38.0 | 35.5 |
| 32 x 66 9 | 4.76 | 47.6 | 43.3 | 39.6 | 36.7 | 34.0 | 31.7 |
| 32 x 66 12 | 5.32 | 53.2 | 48.4 | 44.2 | 40.9 | 38.0 | 35.5 |
| 32 x 66 15 | 6.02 | 60.2 | 54.7 | 50.1 | 46.4 | 43.0 | 40.1 |
| 34 x 72 9 | 5.88 | 58.8 | 53.5 | 49.0 | 45.3 | 42.0 | 39.2 |
| 34 x 72 12 | 6.58 | 65.8 | 59.8 | 54.7 | 50 6 | 47.0 | 43.8 |
| 34 x 72 15 | 7.28 | 72.8 | 66.2 | 60.6 | 56.0 | 52.0 | 48.5 |
| 34 x 78 9 | 6.30 | 63.0 | 57.3 | 52.5 | 48.5 | 45.0 | 42.0 |
| 34 x 78 12 | 7.14 | 71.4 | 64.9 | 59.4 | 54.9 | 51.0 | 47.6 |
| 34 x 78 15 | 8.13 | 81.3 | 73.9 | 67.7 | 62.5 | 58.0 | 54.2 |

The maximum possible capacity is considerably in excess of the figures given, but these represent the grinding rate at which uniformly good work can be maintained.

The installation of a Searby Shredder in any of these installations, after the crusher, can be expected to increase the capacity as much as 20 per cent without affecting the extraction, or to increase the extraction 2.5, 1.25 or 0.8 per cent respectively, depending on whether the installation consists of a 9-, 12- or 15-roller mill, if the grinding rate is not increased. Records are available which indicate grinding rates 50 per cent in excess of the above figures as a direct result of the shredder installation.

## Boilers

Boiler heating surface has been calculated on a basis of fire tube boilers, water tube surface being included as fire tube surface by multiplying it by 1.2. Excluding Honolulu Plantation, which refines its sugar and requires a greater heating surface, the range is from 275 square feet, at Niulii, to 676 square feet at Kohala, the average being 470, which is slightly more than the Hawaiian standard of 450 square feet in fire tube boilers.

Grate area ranges from one square foot per 52.7 square feet of boiler heating surface, to one per 200.0. Excluding the two low and three high figures the range is from 75 to 145 and the average 97.5 is roughly one square foot of grate area per hundred square feet of boiler heating surface.

Combustion volume, as measured to the point where gases first come in contact with boiler tubes or shell, ranges from one cubic foot per 3.125 square feet of boiler surface to one per 14.93. Omitting the four extremely low and five extremely high figures, the range is 5.15 to 9.61 and the average 7.45, so

that one cubic foot of volume to each 7.50 square feet of heating surface may be taken as an average.

Grate area ranges from 1.93 to 7.33 square feet per T. C. H. and combustion volume from 7.10 to 127.2 cubic feet per T. C. H., both of which indicate the extreme variation through which it is possible to obtain passable or even good work.

### Juice Heaters

Tubular juice heaters are used exclusively to heat juices in these Islands, and the baffled type is being rapidly adopted. Heaters are used either for heating or reheating raw juice, or reheating the secondary mixed juice in the case of the Petree process and use live or exhaust steam or vapor from a pre-evaporator as the heating medium.

The various capacities per T. C. H. reported range from 18 to 54.5, the average being 28.8 for mixed juice, as compared with the Hawaiian standard requirement of 35 square feet, and from 9.00 to 22.67 for reheating. In the juice heater, work done is dependent on heating surface and steam pressure, a restricted surface requiring a high steam pressure, a low pressure necessitating a large heating surface. The heating surface required may be calculated from the formula H. S. $\frac{10.23 \times T_d \times J}{T_m \times K}$ where

$T_d$ = temperature rise in F°.
$J$ = tons of juice per ton of cane (1.2 for mixed juice—1.3 for clarified)
$T_m$ = mean temperature difference between juice and steam.
$K$ = decimal figure expressing efficiency of steam with steam at zero gauge as unity. (For each 1 lb. increase or decrease in pressure, increase or decrease the figure 4.4 per cent.)

The calculation indicates 16.7 square feet at 8 pounds gauge, 22.3 at 5 pounds and 33.1 at 2 pounds gauge.

### Settling Tanks

Seven of forty factories report the use of continuous settlers, four using Dorrs, and two the Colonial Sugar Refining type. Of the remaining factories, twenty use cylindrical tanks with conical bottoms, one uses old boilers, three use rectangular tanks with sloping bottoms and five simply designate their tanks as of the intermittent type. Capacities range from 51 to 121.8, the average being 81.2 cubic feet per T. C. H., as compared with the standard requirement of 72 cubic feet.

### Filter Presses

The filtering area ranges from 58.8 to 160.0 square feet per T. C. H., the average being 103.7 where standard practice requires 120 square feet. Excluding the high and low figures 73 per cent of the factories have areas ranging between 91.5 and 134.5 square feet. Filter presses are not used in three Petree process

factories. Kopke centrifugal separators, however, have been installed in one factory to assist in reducing the quantity of impurity in circulation. The centrifugal area now used—0.44 square feet per T. C. H.—is insufficient. An area of one square foot per T. C. H. is recommended in conjunction with Peck strainers using 150-mesh wire cloth.

## Pre-Evaporators

Nineteen factories report this equipment. One has discontinued its use, another uses it as a pre-evaporator "ordinarily" and as the first effect of a quadruple when the mill engines stop; a third uses vapor for heaters and pans, a fourth sends vapors to heaters and the final body of a triple, and one uses vapors for heating, reheating and in a double effect. The remainder is used with triple or quadruple effects.

The pre-evaporator may be installed either as a means of increasing evaporation capacity, or for fuel conservation, or both. It is difficult to state just where a pre-evaporator becomes necessary from a capacity standpoint. Since the capacity of a quadruple effect can be increased 66 per cent by raising the initial pressure from 2 to 8 pounds, and an additional 26 per cent if syrup is sent on at 60 instead of 70 Brix, it is apparent that practically double the amount of work can be done at this station provided those in charge are willing to sacrifice at other stations. Ample pan capacity will warrant passing on the syrup at 60 Brix, and large mill engines will enable the mill to operate against a high back-pressure with a higher steam consumption. Where live steam is used in processing in fairly large quantities and extra fuel is required, the pre-evaporator will ordinarily prove a desirable addition.

Reported pre-evaporator capacities range from 32 to 112.3 square feet of heating surface per T. C. H. The following tabulation indicates the surfaces required when the pre-evaporator is used for heating the entering juices and doing some evaporating, the vapors being used for heating the mixed juice to 212° F., the calandria pressure being as shown:

| | Steam pressure—pounds gauge | | | | |
|---|---|---|---|---|---|
| | 6 | 7 | 8 | 9 | 10 |
| Square feet H. S. for heating | 14 | 9 | 6 | 4 | 3 |
| Square feet H. S. for evaporation | 115 | 64 | 45 | 36 | 30 |
| Total H. S. required | 129 | 73 | 51 | 40 | 33 |

## Evaporators

Ten factories report the use of triple effects, seven of these being in conjunction with pre-evaporators. In the tabulation the surface of triple effects has been expressed as quadruple heating surface by multiplying by 4/3. Heating surfaces range from 160 to 394 square feet per T. C. H. Two hundred twenty-five square feet has been taken arbitrarily as the dividing line between insufficient and sufficient or ample capacity. Six of the factories with surfaces from

211.5 to 223 are just below. Three of these five use pre-evaporators. Three other factories with 160, 181 and 185.3 square feet respectively, appear to be decidedly deficient. The two last are supplemented with ample pre-evaporator capacity which is equivalent to 40-45 square feet in a quadruple. The first with 160 square feet and without an assisting pre-evaporator is apparently hard put to thicken its juices. An excess of heater capacity, however, assists by heating entering juices to the boiling point in the first cell of the evaporator, and a rather unusually large pan capacity enables handling the thin syrup sent to this station, although this is at a sacrifice in steam economy. Three factories report the use of Lillie evaporators in conjunction with standard effects. One uses a horizontal submerged tube evaporator.

The heating surface required in an evaporator is dependent primarily on the steam pressure in the calandria of the first cell, although the density to which evaporation is carried, and the vacuum in the last body each has its effect.

That required under varying conditions is given below:

| Initial pressure | 26" vacuum in last body | | 24" vacuum in last body | |
|---|---|---|---|---|
| pounds gauge | 13–70 Brix | 13–60 Brix | 13–70 Brix | 13–60 Brix |
| 2 | 350 | 303 | 431 | 376 |
| 5 | 255 | 228 | 302 | 271 |
| 8 | 201 | 182 | 232 | 212 |

## The Extra Use of Steam

In view of the diversity in the arrangement and amount of heating surface used in evaporation to syrup, some comment is in order. Since standard arrangement appears to include the quadruple effect the steam requirement with this equipment has been contrasted in the table below with other arrangements:

| | Tons steam per ton cane hour | Per cent |
|---|---|---|
| Exhaust steam to | | |
| Triple, heaters and pans | 0.5924 | 117.7 |
| Triple, pre-evaporators and pans (vapors to heaters) | 0.5432 | 107.8 |
| Quadruple, heaters and pans | 0.5041 | 100.0 |
| Quadruple, pre-evaporators and pans | 0.4734 | 94.0 |
| Quintuple, heaters and pans | 0.4712 | 93.5 |
| Quintuple, pre-evaporators and pans | 0.4217 | 83.7 |

The economy of a quadruple over a triple and pre-evaporator, and of the latter over a straight triple, is apparent. Twelve Hawaiian factories have a pre-evaporator in addition to a quadruple. The tabulation shows a very slight difference in economy in favor of a quintuple over a quadruple and pre-evaporator. The controlling factor undoubtedly is the capacity, for with the same total heating surface, the combination with a pre-evaporator has 15 per cent greater capacity.

## Pan Supply Tanks

Excluding the few extremely low and high valves, the total supply tank capacities range from 60 to 134 and the average is 90.5 cubic feet per T. C. H. for combined syrup, remelt and molasses. In general, this capacity is divided about equally between syrup with remelt, and molasses.

## Vacuum Pans

The following pan capacities are desirable when cane polarizes 14, and syrup purity varies as given below:

| | Syrup gravity purity | | | | | | |
|---|---|---|---|---|---|---|---|
| | 90 | 88 | 86 | 84 | 82 | 80 | 78 |
| Shipping sugar | 42.1 | 41.4 | 40.8 | 40.1 | 39.5 | 38.7 | 37.6 |
| Low grade | 12.2 | 15.6 | 19.2 | 22.9 | 26.8 | 30.9 | 35.2 |
| Total cubic feet | 54.3 | 57.0 | 60.0 | 63.0 | 66.3 | 69.6 | 72.8 |

The required heating surfaces per T. C. H. depend mainly upon the available steam pressures and range from 37.1 square feet at 8 pounds gauge, to 51.5 at 5 pounds, to 60.0 at 4 pounds and to 80.7 square feet at 2 pounds gauge. A ratio of not less than a square foot of heating surface to each cubic foot of capacity is recommended, and if it is at all possible that back pressures are to be reduced below 4 pounds gauge, the additional heating surface should be included, as its cost will be a very small part of the pan installation.

The range for Hawaiian factories is from 23.3 to 98.8 square feet, and 32.8 to 105.2 cubic feet, the average heating surface being 58.7 square feet per T. C. H.

## Vacuum Pump Displacement

The accompanying diagrams (Figs. 1 and 2) indicate the desirable vacuum pump capacities for evaporators and pans when using counter current condensers. The average displacement for factories reporting is 32.8 cubic feet per minute, the range 7.41 to 79.40. The desirable capacities in cubic feet per minute per T. C. H. with vacuum of 27″ in counter current condensers are:

| | Temperature of injection water—° F. | | | | |
|---|---|---|---|---|---|
| | 75 | 80 | 85 | 90 | 95 |
| Pans | 14.4 | 16.8 | 21.6 | 28.2 | 40.2 |
| Quadruple effect | 10.5 | 12.5 | 15.0 | 17.0 | 29.5 |
| Total | 24.9 | 29.3 | 36.6 | 45.2 | 69.7 |
| Pump displacement | 37.4 | 44.0 | 54.9 | 67.8 | 104.4 |

Since a volumetric efficiency of approximately 67 per cent applies to vacuum pumps under these conditions, the desirable total should be increased by 50 per cent so that the required displacement would be as shown.

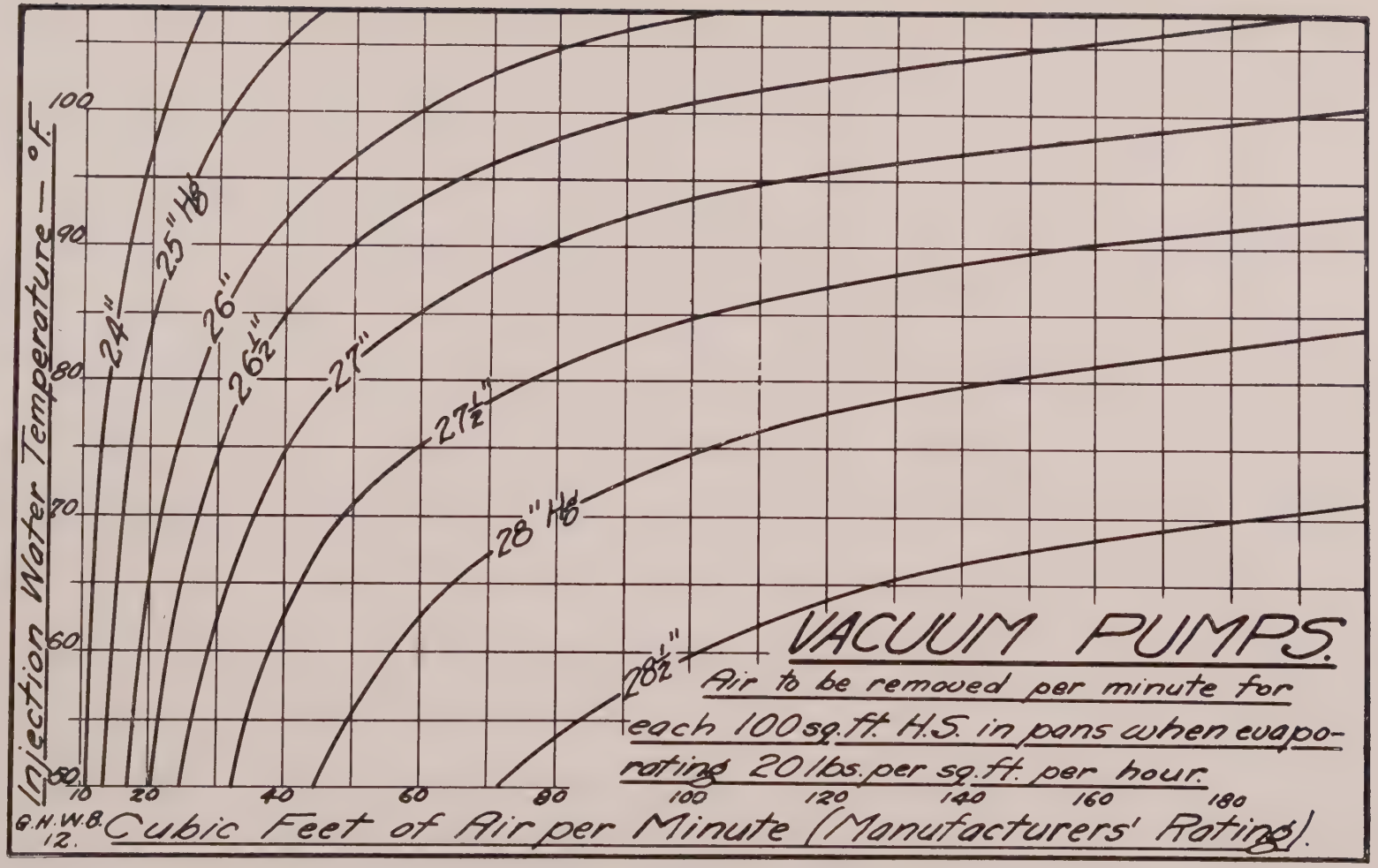

Injection Water Temperature — °F.
100
90
80
70
60
50
24"
25" Hg
26"
26½"
27"
27½"
28" Hg
28½"
VACUUM PUMPS.
Air to be removed per minute for each 100 sq. ft. H.S. in pans when evaporating 20 lbs. per sq. ft. per hour.
10
20
40
60
80
100
120
140
160
180
G.H.W.B. 12.
Cubic Feet of Air per Minute (Manufacturers' Ratings).

Fig 1.

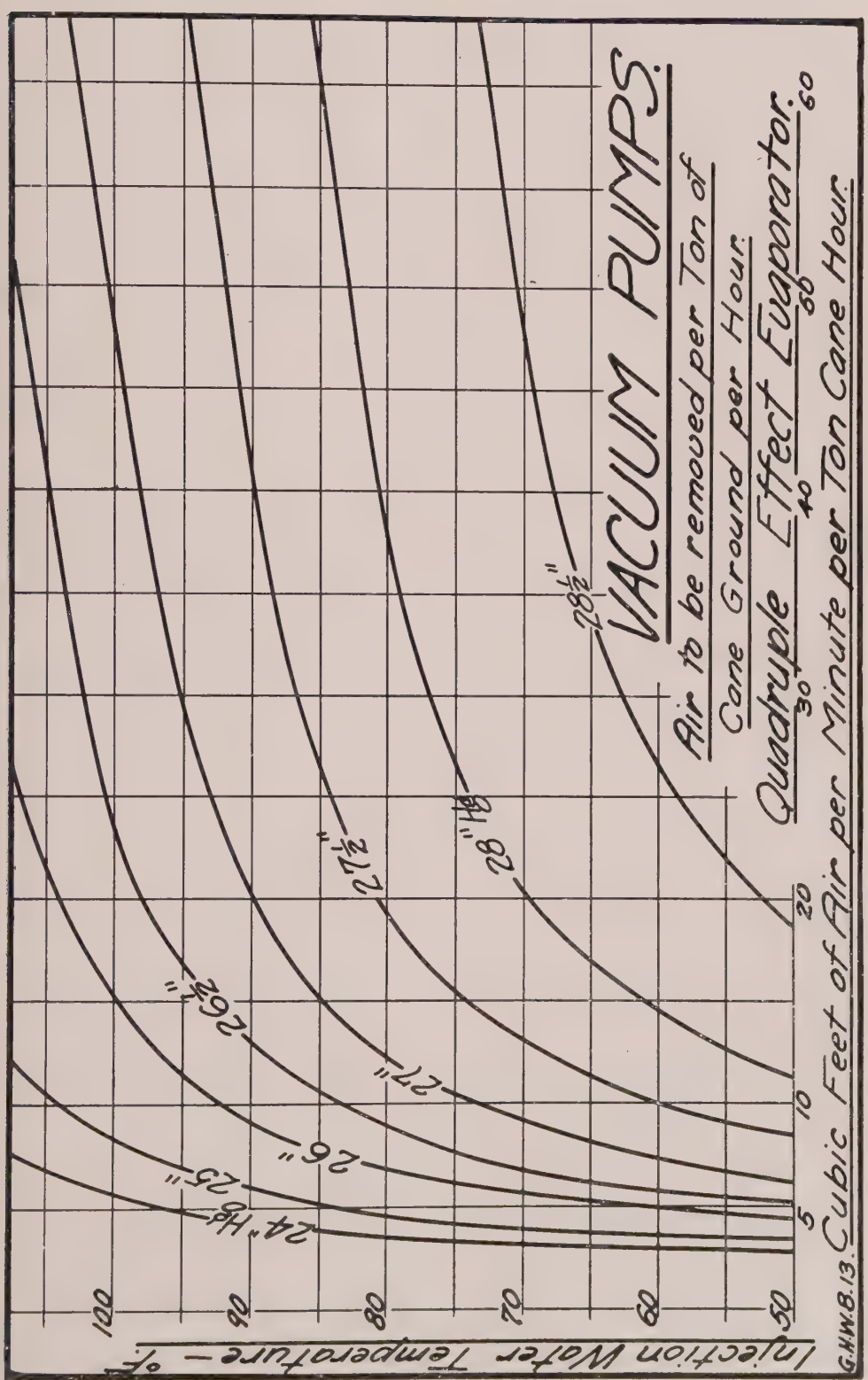

VACUUM PUMPS.
Air to be removed per Ton of Cane Ground per Hour.
Quadruple Effect Evaporator.
Injection Water Temperature — °F.
100
90
80
70
60
50
5
10
20
30
40
50
60
G.H.W.B.13.
Cubic Feet of Air per Minute per Ton Cane Hour.
24" Hg
25"
26"
27"
28"
28½"
26½"
27½"

Fig. 2.

It will be noted that the capacity required varies with the temperature of injection water. Temperatures ranging from 69.8° F. at Paauhau to 110° F. at Olaa have been reported. The latter undoubtedly results when the flume water supply fails during dry years and the cooling pond together with a slight amount of make-up is used at the mill.

### Condenser Water Requirements

The accompanying chart, Fig. 3, is based on a 5° F. drop from vapor to tail water in counter current condensers. The 5° F. drop is thought to be ample, as many installations are operating on a 2-3° F. drop and reputable condenser manufacturers design on the basis of a 1.5° F. drop.

Below are the calculated average quantities of water required per T. C. H.:

| | Temperature of injection water—° F. | | | | |
|---|---|---|---|---|---|
| | 75 | 80 | 85 | 90 | 95 |
| In millions of gallons per day..... | 0.0638 | 0.0740 | 0.0885 | 0.1130 | 0.1542 |
| In gallons per minute..... | 44.4 | 51.5 | 61.5 | 78.7 | 117.4 |

For triple effect evaporation these figures should be increased by 25 per cent; for triple with a pre-evaporator, increased by 10 per cent, and for quadruple with pre-evaporator, decreased by 11 per cent. The maximum instantaneous demand when placing a pan in service might easily be 60 per cent in excess of the average given.

### Crystallizers

Crystallizer capacities range from 161.7 to 492.1 and combined tank and cooler capacities from 491.0 to 1013.5 cubic feet per T. C. H. The capacity required depends upon many factors and may be found from

$$\text{Cu. ft. per T. C. H.} = \frac{3\ \text{PDH} \times (\text{S}-\text{J})\ (\text{s}-\text{M})}{\text{J} \times (\text{s}-\text{j})\ (\text{S}-\text{M})}$$

in which P = Cane polarization.
D = Number of days in crystallizer (including time for filling, emptying and cleaning).
H = Number of hours factory grinds per week.
S = Gravity purity of shipping sugar.
J = Gravity purity of syrup.
M = Gravity purity of final molasses.
s = Gravity purity of second sugar.
j = Gravity purity of second massecuite.

The accompanying chart, Fig. 4, is based on a crystallizer cycle of 12 days, a final molasses purity of 36, final massecuite purity of 55, and second sugar purity of 80. The correction curves at the left indicate the extreme importance of maintaining a low final massecuite and a high second sugar purity. For

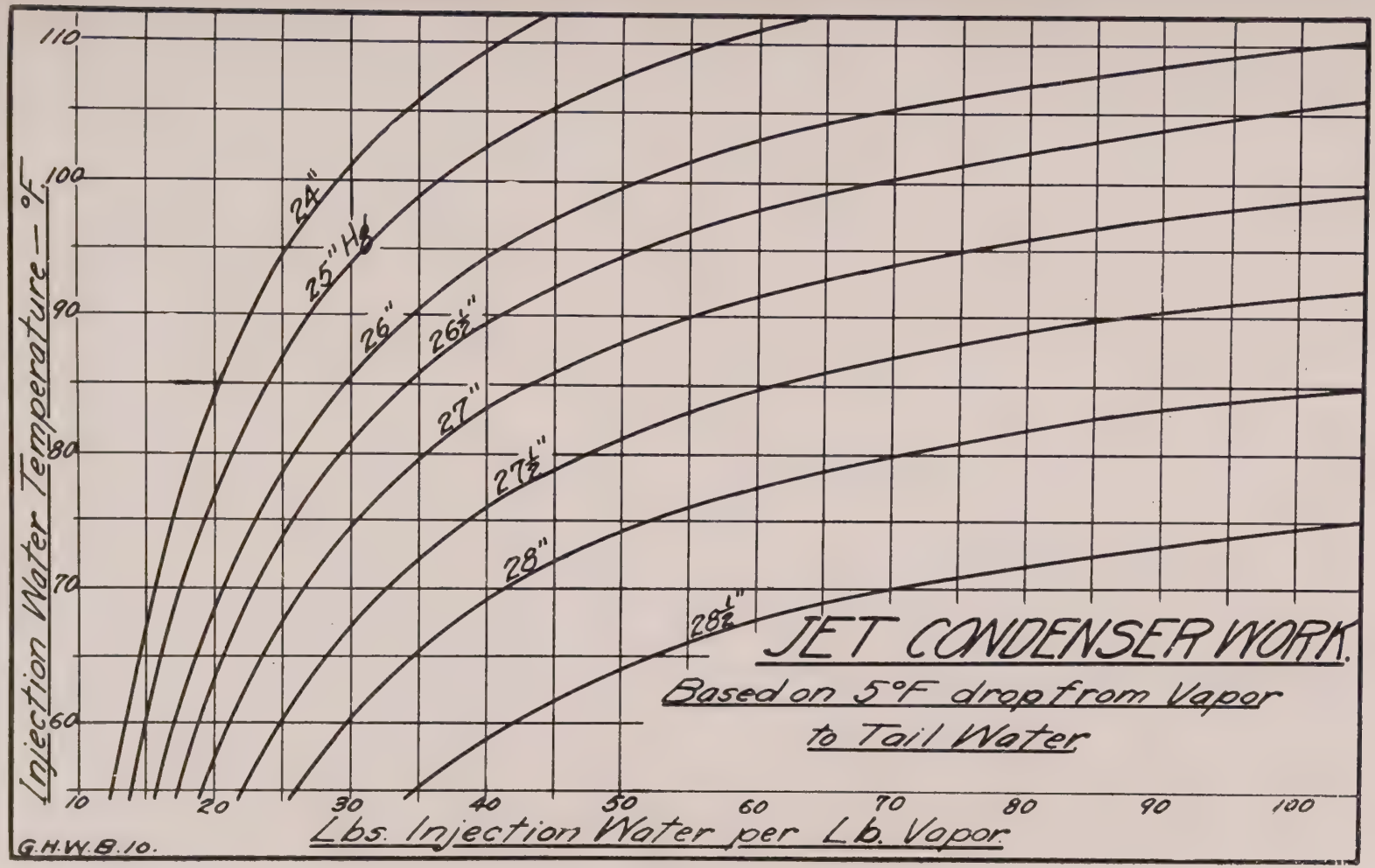

Injection Water Temperature — °F.
110
100
90
80
70
60
24"
25" Hg
26"
26½"
27"
27½"
28"
28½"
JET CONDENSER WORK.
Based on 5°F drop from Vapor to Tail Water
10
20
30
40
50
60
70
80
90
100
Lbs. Injection Water per Lb. Vapor
G.H.W.B.10.

Fig. 3.

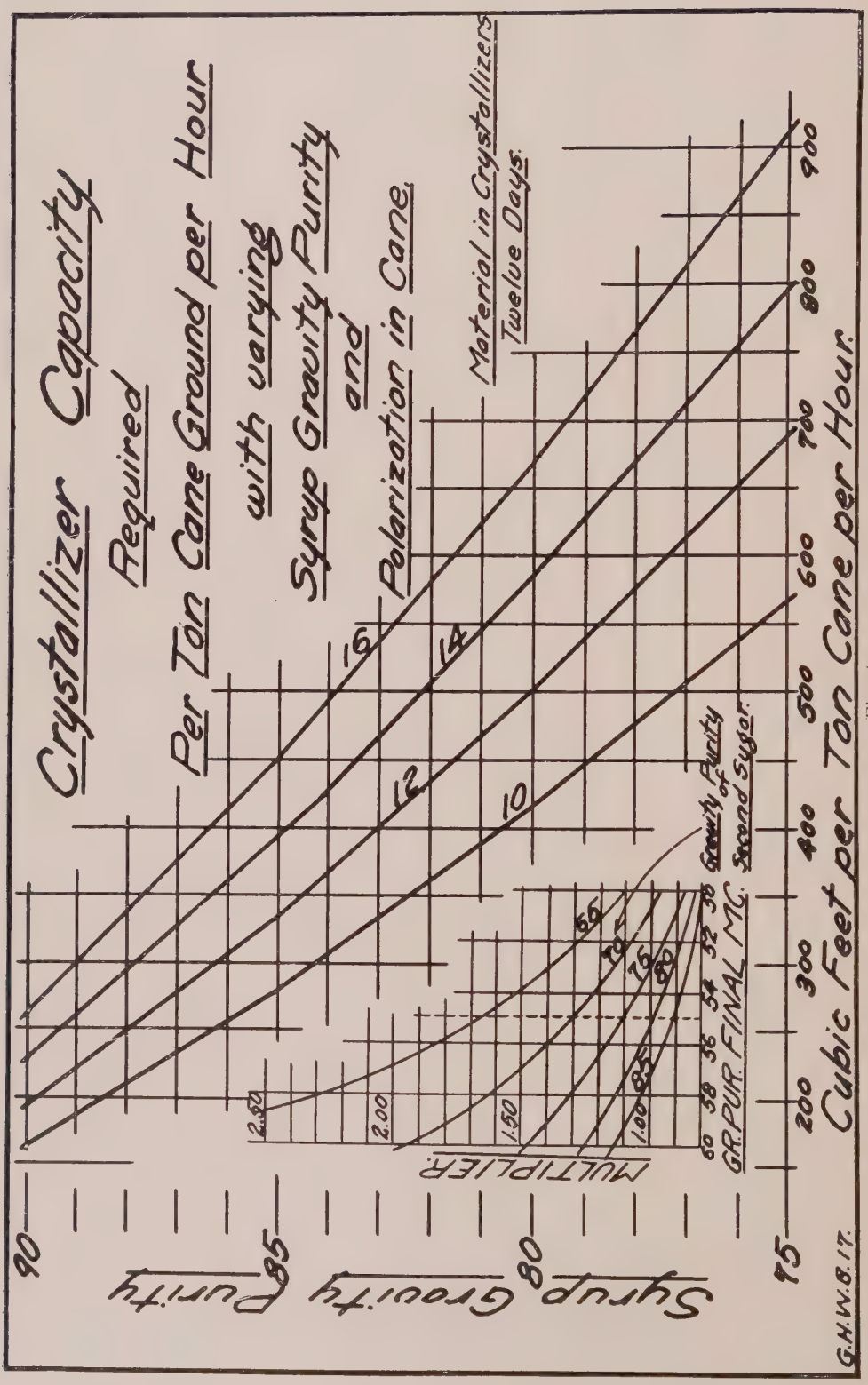

Crystallizer Capacity
Required
Per Ton Cane Ground per Hour
with varying
Syrup Gravity Purity
and
Polarization in Cane.
Material in Crystallizers
Twelve Days.
Syrup Gravity Purity
90
85
80
75
16
14
12
10
MULTIPLIER
2.50
2.00
1.50
1.00
60 58 56 54 52 50
GR.PUR. FINAL MC.
Gravity Purity of Second Sugar.
55
70
75
80
85
200 300 400 500 600 700 800 900
Cubic Feet per Ton Cane per Hour.
G.H.W.8.17.

Fig. 4.

# HAWAIIAN FACTORY EQUIPMENT—October, 1925

| FACTORY | Standard | Kekaha | Koloa | Lihue | Makee | Oahu | Olaa | Pioneer | Waimea | H. C. & S. | Haw'n Sug. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Listed Capacity, T. C. H. | 1 | 40 | 36 | 80 | 50 | 125 | 60 | 90 | 15 | 160 | 50 |
| Milling Equipment | | 2 RC 54<br>15 RM 60 | K<br>2 RC 60<br>12 RM 66 | K<br>2 RC 78<br>S 72<br>12 RM 78 | K<br>2 RC 72<br>S 72<br>9 RM 72 | K<br>2 RC 78<br>S 72<br>12 RM 78 | K<br>S 72<br>12 RM 78 | K<br>2 RC 72<br>S 72<br>15 RM 72 | 2 RC 48<br>12 RM 42 | K(2)<br>2 RC 78<br>S 72<br>12 RM 78 | K<br>2 RC 72<br>S 72<br>12 RM 78 |
| Capacity at Tonnage Ratio of 20 | | 48.4 | 50.4 | 70.4 | 24 | 140.8 | 56.4 | 72 | 20.4 | 140.8 | 70.4 |
| Mill Engines, I. H. P. | | 33.1 | 21.1 | 20.45 | 17.7 | 18.6 | 25.7 | 17.2 | 20.7 | 16.64 | 25.5 |
| Furnaces, Sq. Ft. Grate Area | 4.5 | 3.13 | 4.58 | 2.4 | 3.84 | 1.93 | 2.93 | | | 3.38 | 6.74 |
| Cu. Ft. Combustion Volume | 60 | | 46.70 | | 51.20 | 7.10 | 28.33 | | | 95.21 | 72.92 |
| Boilers Sq. Ft. H. S. (w. t.) | 450 | 325.4 | 346.0 | 328.7 | 373.0 | 331.7 | 366.8 | 415.0 | 420.0 | 349.3 | 505.7 |
| Juice Heaters, Sq. Ft. H. S. Mixed Juice | 35 | 32.5 | 29.0 | 20.9 | 18.0 | 32.0 | 41.8 | 24.3 | 38.0 | 23.65 | 35.1 |
| Clarified Juice | 10 | | | | | | | 20.0 | | 18.41 | |
| Settling Tanks Cu. Ft. | 80 | 53.4 | 51.0 | 61.8 | 73.5 | 83.2 | 81.3 | 78.8 | 62.8 | P. & S.<br>95.53 | 66.84 |
| Filter Presses Sq. Ft. Filter Area | 120 | 73.8 | 114.0 | 58.8 | 84.8 | 67.2 | 81.7 | 71.1 | 50.0 | k | 105.9 |
| Pre-Evaporator Sq. Ft. H. S. | 80 | | | | | 44.0 | | | | 32.99 | |
| Quadruple Effect Sq. Ft. H. S. | 300 | 312.5 | 258.5 | 213.6 | 244.2 | 232.0 | 355.0 | 266.7 | 255.0 | 253.4 | 280.0 |
| Pan Supply Tanks, Cu. Ft. Syrup, Remelt, etc. | 50 | 30.0 | 32.8 | 23.1 | 36.9 | 54.9 | 40.0 | 51.2 | 32.0 | 45.0 | 40.6 |
| Molasses | 50 | 43.2 | 59.7 | 26.2 | 26.5 | | 94.4 | 82.0 | 34.0 | 30.0 | 63.0 |
| Vacuum Pans (P) Shipping Sugar Sq. Ft. H. S. | 40 | 28.1 | 32.2 | 39.3 | 45.5 | 30.4 | 46.7 | 45.4 | 50.0 | 30.4 | 46.6 |
| Shipping Sugar Cu. Ft. | 40 | 37.2 | 30.6 | 40.3 | 46.0 | 30.0 | 51.7 | 43.3 | 42.0 | 32.5 | 43.5 |
| Low Grade Sq. Ft. H. S. | 20 | 18.4 | 25.0 | 14.1 | 10.0 | 24.8 | 43.3 | 33.7 | 6.0 | 29.7 | 32.4 |
| Low Grade Cu. Ft. | 20 | 18.4 | 27.8 | 15.0 | 24.0 | 21.6 | 43.4 | 28.8 | 4.7 | 25.0 | 30.0 |
| Total Sq. Ft. H. S. | 60 | 46.5 | 57.2 | 53.4 | 55.5 | 55.2 | 90.0 | 79.1 | 56.0 | 60.1 | 79.0 |
| Total Cu. Ft. | 60 | 55.6 | 58.4 | 55.3 | 70.0 | 51.6 | 95.1 | 72.1 | 46.7 | 57.5 | 73.5 |
| Vacuum Pump Displacement (v) Cu. Ft. per Minute | 35 | 14.88 | | 8.75 | 79.4 | 7.41 | 59.93 | | | 36.78 | |
| Crystallizers (P) Cu. Ft. | 300 | 320 | 236 | 170 | 260 | 118.4 | 283.3 | 492.1 | 149.3 | 240.0 | 216.4 |
| Centrifugals, Sq. Ft. Screen Area (P) Shipping Sugar | 2.5 | 2.62 | 3.47 | 2.10 | 2.51 | 1.34 | 2.80 | 2.79 | 2.40 | 1.70 | 2.50 |
| Low Grade | 5.0 | 6.23 | 4.08 | 3.20 | 2.93 | 2.36 | 3.50 | 5.85 | 4.10 | 3.28 | 4.40 |
| Total | 7.5 | 8.85 | 7.55 | 5.30 | 5.44 | 3.70 | 6.30 | 8.64 | 6.50 | 4.98 | 6.90 |

| FACTORY | Kahuku | McBryde | Ewa | Kohala | Waialua | Hakalau | Haw'n Ag. | Hilo | Hon. Plt. | Honomu | Hutch'son |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Listed Capacity, T. C. H. | 36 | 40 | 87 | 26 | 70 | 35 | 50 | 40 | 44 | 25 | 30 |
| Milling Equipment | 2 RC 60<br>S 54<br>9 RM 72 | 2 RC 72<br>S 72<br>9 RM 84 | K(2)<br>2 RC 78<br>18 RM 78 | K(2)<br>3 RC 60<br>9 RM 60 | K(2)<br>2 RC 78<br>12 RM 78 | 2 RC 54<br>9 RM 60<br>3 RM 66 | 3 RC 60<br>12 RM 66 | K<br>2 RC 60<br>12 RM 66 | K(2)<br>S 54<br>2 RC 78<br>9 RM 78 | 2 RC 60<br>9 RM 60 | 2 RC 60<br>9 RM 60 |
| Capacity at Tonnage Ratio of 20 | 44.34 | 61.0 | 98.6 | 33.3 | 70.4 | 45.3 | 48.7 | 48.7 | 56.3 | 33.3 | 33.3 |
| Mill Engines, I. H. P. | 14.95 | 17.60 | 18.6 | 23.3 | 15.1 | 27.8 | 21.3 | 22.4 | 13.7 | 31.0 | 28.7 |
| Furnaces, Sq. Ft. Grate Area | 4.00 | 3.20 | | | | 5.55 | | 3.9 | 6.95 | 2.23 | 4.87 |
| Cu. Ft. Combustion Volume | 37.50 | 70.00 | | | | 47.4 | | 63.4 | | | 45.33 |
| Boilers Sq. Ft. H. S. (w. t.) | 511.0 | 666.0 | 633.0 | 676.0 | 347.0 | 557.7 | 624.0 | 493.3 | 837.7 | 445.3 | 564.0 |
| Juice Heaters, Sq. Ft. H. S. Mixed Juice | 33.6 | 40.0 | 25.7 | 32.0 | 28.7 | 37.3 | 36.5 | 39.5 | 33.2 | 41.5 | 19.3 |
| Clarified Juice | | | | | | | | | 15.9 | 10.9 | 22.7 |
| Settling Tanks Cu. Ft. | 98.2 | 95.0 | 92.9 | 67.7 | 91.4 | 69.6 | 113.0 | 99.5 | 66.0 | 72.9 | 82.4 |
| Filter Presses Sq. Ft. Filter Area | 116.7 | 134.5 | 88.9 | 67.0 | 99.6 | 121.1 | 122.0 | 99.2 | 105.0 | 160.0 | 94.2 |
| Pre-Evaporator Sq. Ft. H. S. | | 88.4 | 69.0 | | 85.7 | 85.8 | 94.5 | 99.1 | 90.0 | 72.0 | 69.0 |
| Quadruple Effect Sq. Ft. H. S. | 379.0 | 287.5 | 339.0 | 394.0 | 327.1 | 286.5 | 228.5 | 347.8[t] | 252.0 | 221.2 | 243.2 |
| Pan Supply Tanks, Cu. Ft. Syrup, Remelt, etc. | 55.7 | 60.0 | 40.4 | 48.4 | 43.3 | 47.3 | 26.0 | 55.4 | 32.7 | 26.9 | 18.3 |
| Molasses | 47.6 | 60.0 | 17.4 | 85.6 | 65.0 | 26.7 | 57.6 | 55.4 | 121.8 | 48.0 | 73.3 |
| Vacuum Pans (P) Shipping Sugar Sq. Ft. H. S. | 52.0 | 47.5 | 29.7 | | 39.2 | 32.2 | 34.6 | 28.1 | 21.5 | 39.0 | 20.0 |
| Shipping Sugar Cu. Ft. | 54.4 | 45.0 | 35.1 | | 45.8 | 35.2 | 36.7 | 39.4 | 21.6 | 41.4 | 26.2 |
| Low Grade Sq. Ft. H. S. | 29.9 | 42.0 | 19.8 | | 37.5 | 19.2 | 6.0 | 19.2 | 28.0 | 15.1 | 7.8 |
| Low Grade Cu. Ft. | 23.0 | 21.2 | 22.9 | | 24.7 | 21.3 | 8.0 | 20.6 | 39.9 | 13.1 | 14.6 |
| Total Sq. Ft. H. S. | 81.9 | 89.5 | 49.5 | 68.1 | 76.7 | 51.4 | 40.6 | 47.3 | 49.5 | 54.1 | 27.8 |
| Total Cu. Ft. | 77.4 | 66.2 | 58.0 | 65.0 | 70.5 | 56.5 | 44.7 | 60.0 | 61.5 | 54.5 | 40.8 |
| Vacuum Pump Displacement (v) Cu. Ft. per Minute | | | 17.42 | 35.5 | | 23.55 | | 23.95 | 26.05 | 27.02 | |
| Crystallizers (P) Cu. Ft. | 208.0 | 337.5 | 329.0 | 233.5 | 320.0 | 259.0 | 290.5 | 199.1 | 487.0 | 200.1 | 865.7[c] |
| Centrifugals, Sq. Ft. Screen Area (P) Shipping Sugar | 2.32 | 3.10 | 1.92 | | 1.80 | 2.39 | 3.35 | 3.14 | 2.10 | 3.35 | 2.79 |
| Low Grade | 4.73 | 5.20 | 6.19 | | 4.20 | 3.81 | 5.00 | 5.23 | 2.10 | 5.13 | 4.88 |
| Total | 7.05 | 8.30 | 8.11 | 5.69 | 6.00 | 6.20 | 8.35 | 8.37 | 4.20 | 8.48 | 7.67 |

| FACTORY | Kilauea | Onomea | Olowalu | Paauhau | Pepeekeo | Wailuku | Waimanalo | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Listed Capacity, T. C. H. | 24 | 48 | 15 | 30 | 30 | 42 | 26 | 15 | 30 | 25 | 25 | 30 | 18 | 20 | 25 | 40 | 26 | 72 | 75 | 40 |
| Milling Equipment | K S<br>3 RC 60<br>9 RM 60 | 2 RC 60<br>S 54<br>12 RM 66 | K<br>3 RC 48<br>9 RM 48 | 2 RC 60<br>12 RM 66 | 2 RC 54<br>9 RM 60 | K<br>2 RC 72<br>12 RM 78 | K<br>3 RC 54<br>9 RM 54 | K<br>2 RC 60<br>6 RM 50 | K<br>2 RC 60<br>12 RM 60 | K<br>2 RC 54<br>9 RM 60 | K<br>2 RC 60<br>9 RM 60 | K<br>2 RC 60<br>9 RM 60 | K<br>9 RM 54 | K<br>9 RM 60 | K<br>S 42<br>2 RC 60<br>9 RM 60 | K(2)<br>2 RC 66<br>12 RM 66 | K(2)<br>12 RM 60 | 3 RC 78<br>12 RM 78 | K(2)<br>3 RC 66<br>18 RM 66 | K(2)<br>2 RC 5[illegible]<br>12 RM 54 |
| Capacity at Tonnage Ratio of 20 | 33.3 | 48.7 | 21.3 | 48.7 | 45.3 | 68.3 | 27.0 | 19.9 | 43.7 | 45.3 | 33.3 | 33.3 | 20.2 | 25.0 | 45.3 | 50.4 | 33.3 | 70.4 | 70.6 | 33.8 |
| Mill Engines, I. H. P. | 26.7 | 22.0 | 39.8 | 34.4 | 18.1 | 22.4 | 20.9 | 10.1 | 23.1 | 11.4 | 17.95 | 27.00 | 13.95 | 21.05 | 18.35 | 19.1 | 23.1 | | | |
| Furnaces, Sq. Ft. Grate Area | 7.25 | 3.97 | 6.4 | 6.25 | 4.77 | 4.62 | 7.33 | | | | | | | | | | 3.98 | 7.75 | | |
| Cu. Ft. Combustion Volume | 68.8 | 38.60 | 36.70 | 95.50 | 47.33 | 67.30 | 127.2 | | | | | | | | | | 36.7 | 79.80 | | |
| Boilers Sq. Ft. H. S. (w. t.) | 514.0 | 388.7 | 548.3 | 597.2 | 454.9 | 327.0 | 557.0 | 359.0 | 417.0 | 547.0 | 400.0 | 488.0 | 275.0 | 371.0 | 542.0 | 375.0 | 391.0 | 502.0 | | |
| Juice Heaters, Sq. Ft. H. S. Mixed Juice | 22.9 | 27.1 | 26.1 | 33.0 | 35.0 | 30.1 | 37.4 | 39.5 | 39.8 | 22.1 | 21.5 | 23.9 | 33.6 | 33.2 | 54.5 | 31.9 | 30.7 | 36.9 | 50.0 | 25.0 |
| Clarified Juice | | | | | 9.0 | | | | | | | | | | | | | | | |
| Settling Tanks Cu. Ft. | 103.6 | 63.8 | 118.0 | 80.1 | 70.0 | 105.5 | 76.4 | 79.9 | P. & S.<br>121.8 | 91.8 | 67.2 | 79.5 | 70.6 | 103.0 | 72.3 | 65.8 | 101.8 | 113.2 | P. & S. | |
| Filter Presses Sq. Ft. Filter Area | 135.5 | 95.0 | 121.7 | 141.3 | 105.0 | 97.2 | 130.4 | 83.7 | Petree Process | 95.5 | 91.5 | 116.7 | 93.8 | 130.0 | 102.8 | 121.8 | 103.9 | 113.2 | Petree Process | 70.0 |
| Pre-Evaporator Sq. Ft. H. S. | 51.3 | 62.5 | 104.54 | | 83.0 | 96.0 | | | | 32.0 | 103.9 | | | 112.3 | | | | 90.85 | | |
| Quadruple Effect Sq. Ft. H. S. | 223.0[t] | 250.0 | 270.7[t] | 281.5 | 280.0[t] | 261.5 | 308.4 | 214.0[t] | 329.0 | 219.0[t] | 185.5[t] | 330.4 | 211.5[t] | 181.0[t] | 160.0 | 291.0 | 270.0 | 280.0 | 433.0 | 394.0[t] |
| Pan Supply Tanks, Cu. Ft. Syrup, Remelt, etc. | 55.2 | 26.3 | 37.8 | 38.7 | 35.0 | 51.5 | 30.0 | 47.8 | 36.9 | | 21.2 | 20.0 | 61.2 | 45.5 | 28.2 | 16.2 | 33.6 | 50.0 | | |
| Molasses | 22.8 | 33.7 | 25.2 | 21.0 | 38.0 | 51.0 | 30.0 | 45.3 | 49.5 | | 74.6 | 32.7 | 64.0 | 43.5 | 32.8 | 25.9 | 21.9 | 50.0 | | |
| Vacuum Pans (P) Shipping Sugar Sq. Ft. H. S. | 72.7 | 34.4 | 42.2 | 44.2 | 42.0 | 41.9 | 46.2 | | 45.1 | | 36.1 | 45.5 | | 30.5 | 66.9 | 42.9 | | | | |
| Shipping Sugar Cu. Ft. | 76.9 | 33.4 | 42.2 | 44.9 | 39.0 | 41.9 | 46.2 | | 40.7 | | 31.6 | 50.8 | | | 54.0 | 44.6 | | | | |
| Low Grade Sq. Ft. H. S. | 26.1 | 14.9 | 10.0 | 17.0 | 26.0 | 33.4 | 23.1 | | 7.9 | | 9.2 | 8.5 | | 7.75 | 7.7 | 21.9 | 5.8 | | | |
| Low Grade Cu. Ft. | 28.3 | 18.1 | 10.0 | 13.6 | 27.0 | 33.4 | 23.1 | | 11.0 | | 10.4 | 8.7 | | | 4.9 | 25.2 | 7.7 | | | |
| Total Sq. Ft. H. S. | 98.8 | 49.3 | 52.2 | 61.2 | 68.0 | 75.3 | 69.3 | 40.6 | 53.0 | 30.4 | 45.3 | 54.0 | 23.3 | 38.25 | 74.6 | 64.8 | 39.5 | 51.5 | 132.0 | 39.0 |
| Total Cu. Ft. | 105.2 | 51.5 | 52.2 | 58.5 | 66.0 | 74.8 | 69.3 | 40.7 | 51.7 | | 42.0 | 59.5 | 33.3 | | 58.9 | 69.8 | 31.0 | 52.5 | | |
| Vacuum Pump Displacement (v) Cu. Ft. per Minute | 63.80 | | | 22.00 | 25.62 | 30.50 | 55.80 | | | | | | | | | | 31.6 | | | |
| Crystallizers (P) Cu. Ft. | 164.5 | 161.7 | 1010.8[c] | 1013.5[c] | 211.0 | 290.0 | 354.0 | 491.0[c] | 942.3[c] | 809.0[c] | 750.6[c] | 826.1[c] | 841.0[c] | 427.8 | 705.0[c] | 267.0 | 1054.5[c] | 483.0 | 140.0 | 366.0 |
| Centrifugals, Sq. Ft. Screen Area (P) Shipping Sugar | 3.50 | 2.61 | 3.70 | 2.79 | 2.79 | 2.01 | 3.22 | 2.44 | 4.19 | 2.92 | 2.93 | 2.79 | 2.03 | 1.83 | 2.93 | 3.14 | 3.01 | 2.33 | 1.70 | 3.0[illegible] |
| Low Grade | 4.17 | 4.36 | 2.50 | 4.13 | 5.58 | 7.50 | 4.83 | 3.66 | 4.27 | 2.19 | 1.46 | 5.49 | 4.07 | 3.66 | 2.56 | 5.83 | 1.81 | 4.66 | 2.90 | 1.60 |
| Total | 7.67 | 6.97 | 6.20 | 6.92 | 8.37 | 9.51 | 8.05 | 6.10 | 8.46 | 5.11 | 4.39 | 8.28 | 6.10 | 5.49 | 5.49 | 8.97 | 4.82 | 6.99 | 4.60 | 7.60 |

w. t. —Water tube heating surface included as fire tube by multiplying by 1.2.
P. & S.—For primary and secondary juices. Petree Process).
k —Kopke clarifiers 0.44 sq. ft. per T. C. H. Recommended capacity 1.0 sq. ft. per T. C. H.

t —Triple effect-heating surface expressed as quadruple heating surface by multiplying by 4/3.
c—Coolers or tanks without stirrers.
Pre-evaporator connected to be used when required as first body of a quintuple,[5] or quadruple.[4]

*—As reported in 1919.
v—Vacuum pump displacement required varies with temperature of injection water.
P—Capacities in pans, crystallizers and centrifugals depend to a great extent on juice purity. Standards used are fair averages.

example, increasing the massecuite purity to 58 and decreasing sugar purity to 70 will increase the quantity of low grade 61 per cent.

It is noticeable that ten of the factories, which, however, produce but slightly over 11 per cent of the Hawaiian crop, are still using tanks and coolers exclusively, holding low grades up to 60 days.

The tendency and modern practice is to boil to grain, and drop to crystallizers where motion is maintained until the possibility of the formation of false grain is past. The water-cooled crystallizer, which has just been developed in the Philippines, promises to reduce this time considerably. In fact, there are some who advocate crystallizers to hold massecuite two days only, the remainder of the cooling being done in tanks without stirrers.

### Centrifugals

Screen area in shipping sugar machines ranges from 1.34 to 4.19, in low grade machines from 1.46 to 7.50, and total centrifugal screen area from 3.70 to 9.51 square feet per T. C. H. The requirements when the shipping sugar cycle averages 10 minutes, and the low grade cycle 60 minutes, are as follows:

| | Gravity purity of syrup | | | | | | |
|---|---|---|---|---|---|---|---|
| | 90 | 88 | 86 | 84 | 82 | 80 | 78 |
| Shipping sugar | 2.845 | 2.805 | 2.760 | 2.710 | 2.666 | 2.612 | 2.555 |
| Low grades | 2.292 | 2.901 | 3.568 | 4.250 | 4.970 | 5.745 | 6.530 |
| Total | 5.137 | 5.706 | 6.328 | 6.960 | 7.636 | 8.357 | 9.085 |

## The Baffle Juice Heater*

By Seymour Terry

This subject of the baffle juice heater has been presented before, but the advantages of this design over the old style heater, while not always taken advantage of, are so well assured that it is thought worth while to bring out its good points again. The picture which accompanies this article shows two such heaters in the shops of the Honolulu Iron Works Company, each having 7 tubes per pass, 22 passes and 829 square feet of surface (see Fig. 1). The covers are of cast iron designed on the girder principle and carried by hinges cast with the covers and heads. The heads are made of bronze, which, though of slighty higher first cost, is a safeguard against cracking, the fate of many cast-iron heads. The expensive swing bolts common on the old heater are replaced with standard machine bolts for which sufficient distance is allowed between the head and flanges to enable inserting them from the back. To open the heater door, the nuts are taken off

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

and the bolts pushed back, leaving them in place. Cast iron is quite satisfactory for the flanges and steel plate for the shell of thickness to suit the different diameters. The baffle plates (see Fig. 2) are 3/16″ steel plate shelves secured to the shell and arranged to give a decrease of cross section to the steam flow as condensation takes place, thus maintaining an approximately steady velocity of steam. The greater condensation takes place on the lower tubes due to the greater temperature difference at this part of the heater, and the reduction in the number of tubes between baffles gives better tube drainage where it is needed. The tubes are 1½″ O. D. copper No. 16 gauge 15′-0″ long. This is probably the maximum length that can be used without a center support and yet allows of rolling in both heads, which is an advantage over having to use ferrules. In place of the regular electrolytic copper, the tubes can be furnished of a special grade known as Lake fire refined arsenical copper having impurities other than silver and arsenic not in excess of 0.12 per cent, arsenic content to be between .05 per cent and 0.10 per cent. As to the advantages on operation of this heater over the old style, there are two main features:

*First:* The condensate on the tubes, instead of dripping from tube to tube and so forming a wet coating on the lower tubes through which the heat of the heating steam has to traverse, is collected by the baffle plates and drained to the sides of the heater. When consideration is taken of the fact that in a 900 square feet heater about 12,000 lbs. of water per hour are drained away, this advantage is quite evident.

*Second:* The heating steam is kept at an effective velocity in a definite direction right through the heater. This steam flow is in part a counter flow to the juice.

Several of these heaters are now in operation in Hawaii. It is generally accepted that the old style heater would heat 60 to 70 lbs. of juice per hour per square foot from 80° to 212° F. with 5 lbs. of heating steam. A baffle heater in the Islands is reported as heating 124 lbs. of juice per square foot per hour with steam at 6 lbs. pressure and juice temperature from 90° F. to 217° F.

The work done by heaters is indicated by the number of the B. T. U.'s transmitted across a square foot of tube surface for each degree temperature difference per minute and is known as the heat transmission coefficient. To facilitate calculations for heaters, the curves in Fig. 3 have been plotted assuming the initial juice temperature to be 80° F. and heating steam to be 0 lb. to 8 lbs. gauge pressure.

The following table gives the old standard heaters at 70 lbs. per square foot per hour and the results from the above mentioned baffle heater. M is the mean temperature difference, B is B. T. U.'s per minute per square foot:

| | Pressure of steam lbs. | M | B | B / M | Speed through tube ft. per second | Lbs. juice per sq. ft. per hour |
|---|---|---|---|---|---|---|
| Standard heater | 5 | 58.5 | 138.5 | 2.36 | 5.00 | 70 |
| Baffle heater | 6 | 53.4 | 236 | 4.42 | 4.96 | 124 |

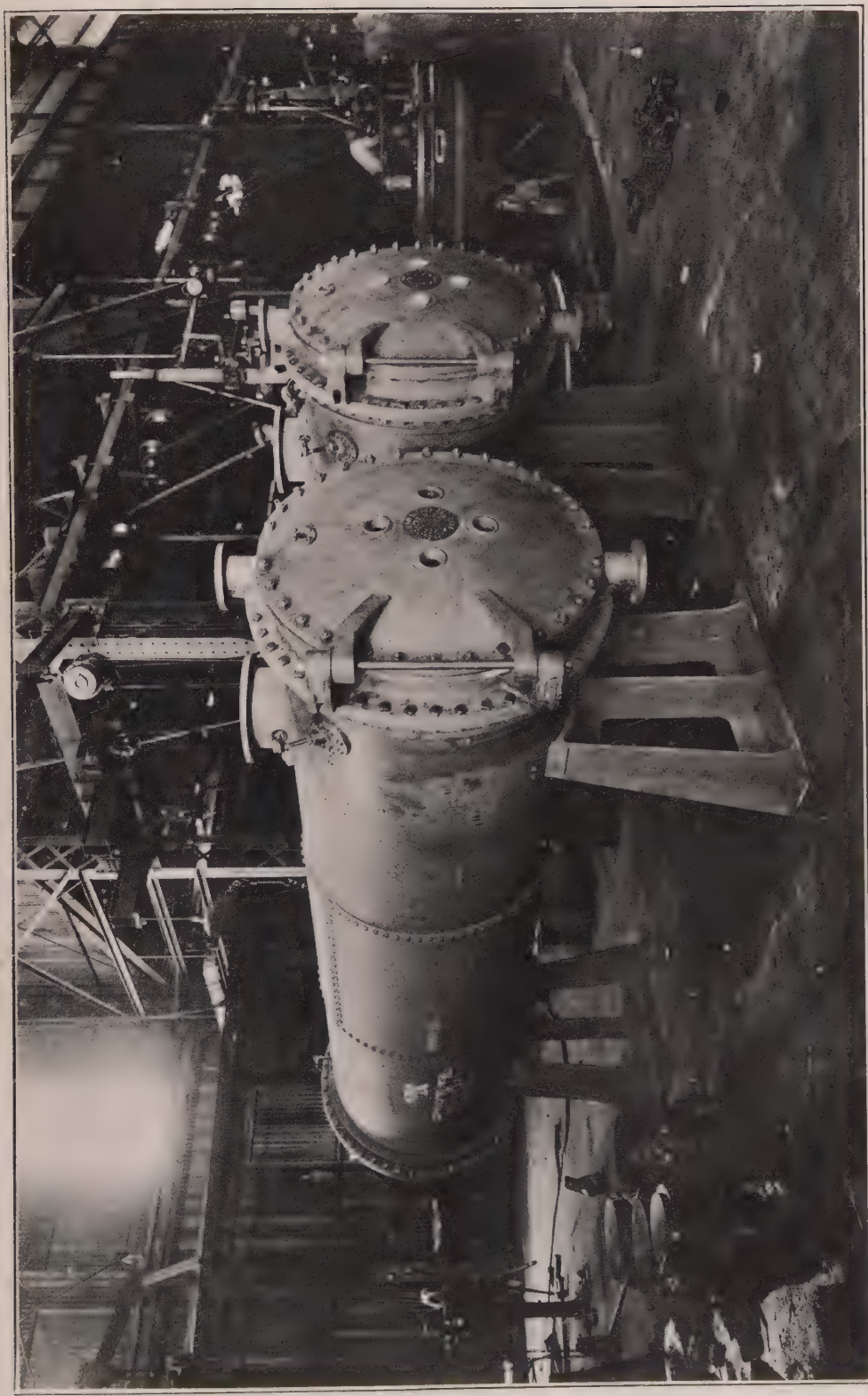


Fig 1.

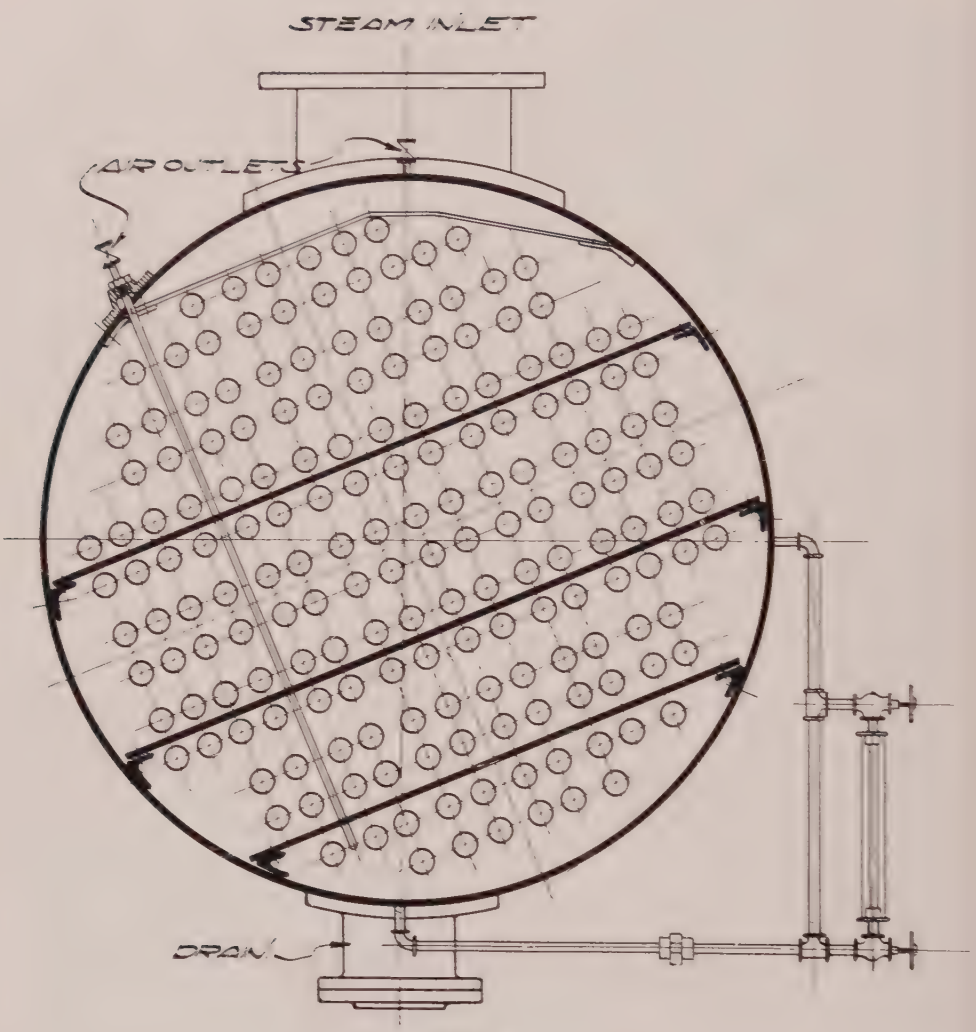



Fig. 2.

$\frac{B}{M}$ — is the heat transmission coefficient.

Juice density 1 = assumed at 65.5 lbs. per cubic foot and specific heat 0.9. No allowance for radiation.

## Selection of Heaters

The accompanying table will be found useful in selecting new heaters and when considering the changing over of old heaters to baffle type. The diameter of the shell in the first column gives choice of different numbers of tubes per pass to suit juice tonnage. The table is based on a speed of 5 feet per second in the 22-pass heaters, the juice passing through the tubes in 66 seconds. This time is kept constant for all the heaters, the juice speeds varying with the number of passes, the tonnage with the passes and tubes per pass.

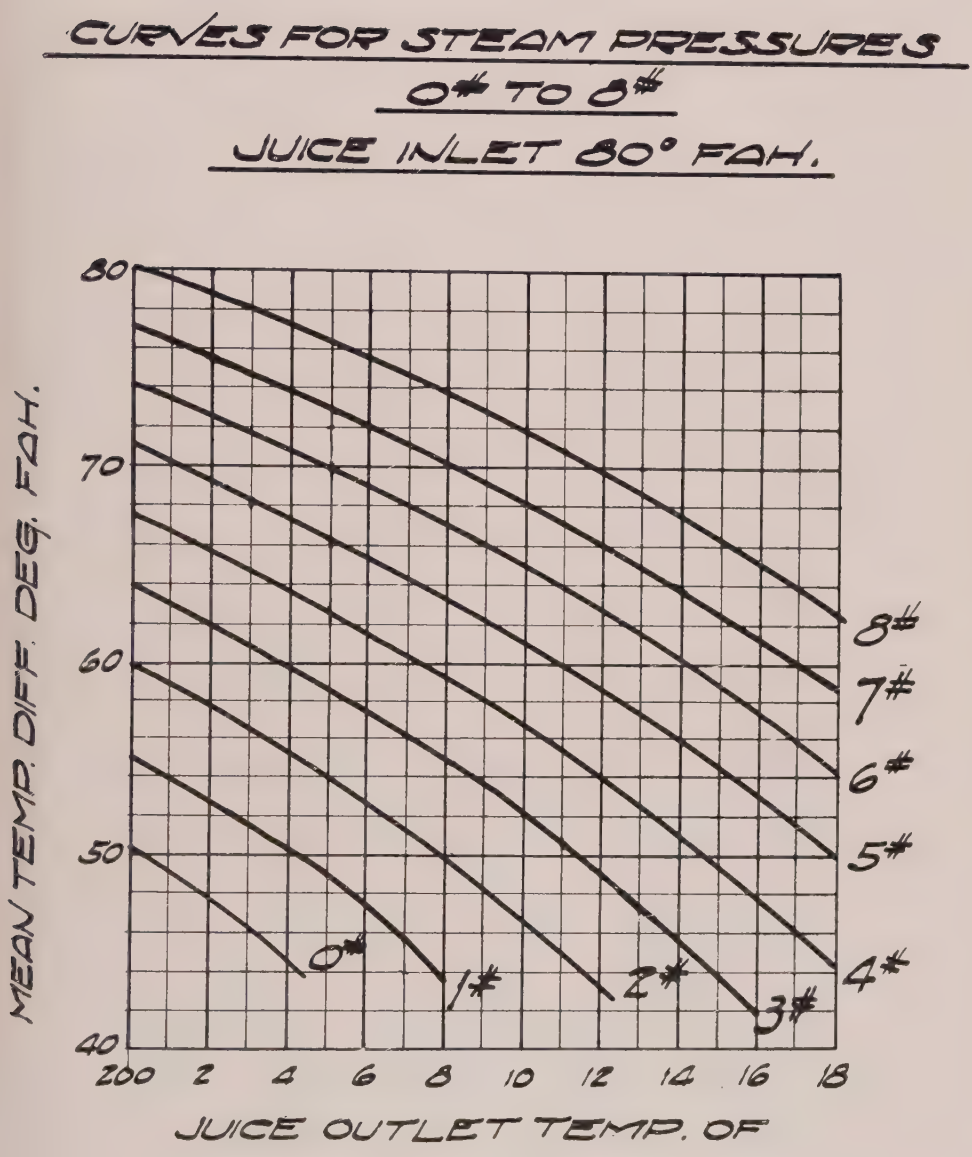

CURVES FOR STEAM PRESSURES
0# TO 8#
JUICE INLET 80° FAH.
MEAN TEMP. DIFF. DEG. FAH.
80
70
60
50
40
200
2
4
6
8
10
12
14
16
18
JUICE OUTLET TEMP. OF
0#
1#
2#
3#
4#
5#
6#
7#
8#

Fig. 3.

BAFFLE HEATERS

| Ins. dia. of shell | No. of tubes per pass | No. of passes | Total No. of tubes | Sq. ft. heating surface Ins. tubes | Outs. tubes | Tons juice per hour | Speed feet per min. | Time in heater seconds |
|---|---|---|---|---|---|---|---|---|
| 2′ 7″ | 3 | 16 | 48 | 258 | 282 | 13.2 | 3.63 | 66 |
| 2′ 7″ | 4 | 16 | 64 | 344 | 376 | 17.5 | 3.63 | 66 |
| 2′ 9″ | 3 | 18 | 54 | 290 | 318 | 14.8 | 4.1 | 66 |
| 2′ 9″ | 4 | 18 | 72 | 387 | 424 | 19.7 | 4.1 | 66 |
| 3′ 0″ | 3 | 26 | 78 | 420 | 459 | 21.4 | 5.91 | 66 |
| 3′ 0″ | 4 | 20 | 80 | 430 | 471 | 21.9 | 4.55 | 66 |
| 3′ 0″ | 5 | 16 | 80 | 430 | 471 | 21.9 | 3.63 | 66 |
| 3′ 0″ | 6 | 16 | 96 | 516 | 566 | 26.3 | 3.63 | 66 |
| 3′ 3″ | 4 | 22 | 88 | 473 | 518 | 24.1 | 5.00 | 66 |
| 3′ 3″ | 4 | 24 | 96 | 516 | 566 | 26.3 | 5.45 | 66 |
| 3′ 3″ | 5 | 18 | 90 | 484 | 530 | 24.7 | 4.1 | 66 |
| 3′ 3″ | 6 | 18 | 108 | 580 | 635 | 29.6 | 4.1 | 66 |
| 3′ 6″ | 4 | 26 | 104 | 560 | 613 | 28.5 | 5.91 | 66 |
| 3′ 6″ | 5 | 20 | 100 | 538 | 589 | 27.4 | 4.55 | 66 |
| 3′ 6″ | 5 | 22 | 110 | 592 | 648 | 30.1 | 5.00 | 66 |
| 3′ 6″ | 6 | 20 | 120 | 646 | 707 | 32.9 | 4.55 | 66 |
| 3′ 6″ | 6 | 22 | 132 | 710 | 778 | 36.1 | 5.00 | 66 |
| 3′ 9″ | 5 | 24 | 120 | 646 | 707 | 32.9 | 5.45 | 66 |
| 3′ 9″ | 6 | 24 | 144 | 775 | 848 | 39.5 | 5.45 | 66 |
| 4′ 0″ | 5 | 26 | 130 | 699 | 766 | 35.5 | 5.91 | 66 |
| 4′ 0″ | 6 | 26 | 156 | 839 | 919 | 42.7 | 5.91 | 66 |
| 4′ 0″ | 7 | 20 | 140 | 753 | 825 | 38.3 | 4.55 | 66 |
| 4′ 0″ | 7 | 22 | 154 | 829 | 907 | 42.2 | 5.00 | 66 |
| 4′ 0″ | 8 | 20 | 160 | 861 | 942 | 43.8 | 4.55 | 66 |
| 4′ 0″ | 8 | 22 | 176 | 947 | 1037 | 48.2 | 5.00 | 66 |
| 4′ 3″ | 7 | 24 | 168 | 904 | 990 | 46.0 | 5.45 | 66 |
| 4′ 3″ | 8 | 24 | 192 | 1033 | 1131 | 52.6 | 5.45 | 66 |
| 4′ 6″ | 7 | 26 | 182 | 979 | 1072 | 49.8 | 5.91 | 66 |
| 4′ 6″ | 8 | 26 | 208 | 1119 | 1225 | 57.0 | 5.91 | 66 |

Copper tubes 1½″ O. D. No. 16 Stubb's gauge 15′ 0″ long. Lbs. of juice per sq. ft. per hour 102.

The pounds of juice per square foot per hour are 102 in all cases. If, in the heaters where the speed is 5 feet per second, it is assumed that a steam pressure of 5 lbs. gauge will heat the juice from 80° F. to 212° F., then the mean temperature difference is 58.5 and the B. T. U.'s per square foot per minute are 203, giving a heat transmission coefficient of 3.47.

Assuming heat transmission coefficients to vary as the cube root of the juice velocity, curve 3 has been plotted giving heat transmission coefficients for juice velocities from 3 to 8 feet per second with 5 feet per second and $\frac{B}{M} = 3.47$ as a base (see Fig. 4).

By the use of these curves, the effect of a change in juice velocity from the assumed standard of 5 feet per second can be found. For instance, the 8-tube per pass 26-pass heater has a table velocity of 5.91 feet per second. From curve 3 the heat transmission coefficient is 3.67; this divided into the B. T. U.'s per

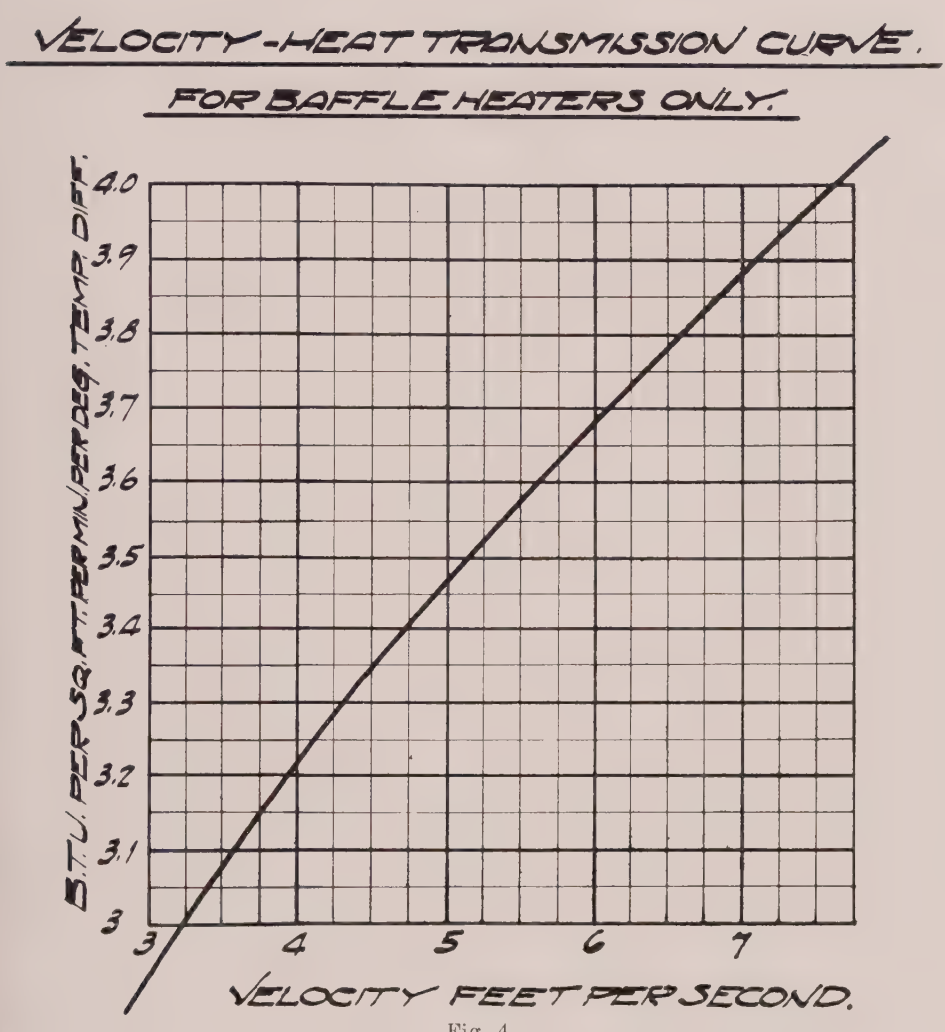



Fig. 4.

square foot per minute of 203 gives a mean temperature difference of 55.4. By now referring to curve 2 with a juice temperature from 80° to 212° F., the steam pressure required will be 4¼ lbs. gauge. If the juice tonnage is changed from that given in the table, then the heat transmission of 203 will change in proportion. For instance, if the 8-tube per pass 26-pass heater had 50 tons in place of 57, then the heat transmission would be 177 B. T. U.'s per square foot per minute and the velocity 5.18 feet per second. From curve 3, the heat transmission coefficient is 3.51 which, divided into 177, gives 50.4 mean temperature difference. From curve 2 a steam pressure for juice at 212° F. is about 3¼ lbs. Under this condition, the juice is 75 seconds in passing through the tubes.

In the case of the slow velocity heater, when increasing the tonnage, the steam pressure will have to be increased. Taking the 7-tube 20-pass heater at 38.3 tons and 4.55 feet per second, increased to 50 tons and 5.92 feet per second,

gives a heat transmission of 265 B. T. U.'s and a coefficient of 3.67, which is a mean temperature difference of 72.2 and from curve 2 a steam pressure of 8¼ lbs. In this case the time of the juice in the heater is 50.5 seconds.

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# A Brief Sketch of the Development of the Saccharimeter*

By F. T. Dillingham

By plane-polarized light is meant light all of whose vibrations lie in a single plane.

The polarization of light was first noticed in 1678 by Huygens while studying the refraction of light in a crystal of Iceland spar. In 1808, it was discovered that polarization could also be produced by reflection.

If a beam of light falls upon a smooth surface of a transparent substance it is decomposed into reflected and refracted rays. The reflected rays at a definite angle of incidence are completely polarized, the plane of the lines of incidence and reflection being the plane of polarization. The angle of incidence at which reflected light is completely polarized is called the polarizing angle and varies according to the refractive power of the reflecting substance. The polarizing angle of glass of refractive index 1.54 ($n = 1.54$) is about 57 degrees. (Fig. 1.)

Of several devices which are available for producing plane-polarized light, a modified crystal of Iceland spar or calc spar is the only one used in the construction of polariscopes and saccharimeters. Calc spar is a pure, crystallized form of calcium carbonate. It is very soft (number three in the scale of hardness), and easily decomposed by the action of heat and acids; hence great care must be taken to handle Nicol prisms gently. Calc spar is a clear, transparent mineral which easily cleaves into rhombohedral prisms. If a small object is examined through such a rhombohedron, the image will be seen as doubled. Rays of light in passing through the crystal undergo double refraction, that is, they take two paths through the crystal. This phenomenon is noticeable in any position of the calc spar rhombohedron except in a direction parallel to the diagonal, joining the two opposite obtuse corners, known as the optical axis of the crystal. (Fig. 2.)

Before a crystal of calc spar can be used in the construction of a polariscope it must be modified so as to eliminate one set of the component rays. The best known method of so doing is as follows: A rhombohedron of calc spar, ABCD, is selected, the length of which is about three times its width. At each end of the crystal, wedge-shaped sections, ADE and BFC, are removed in such a way as to reduce the acute angles DAB and BCD from 71 degrees to 68 degrees. That is, the end faces of the crystal are ground and polished so they make an angle of 68 degrees with the long edges instead of 71 degrees of the original crystal. Then the crystal is cut in halves or ground along a plane passing through one of

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

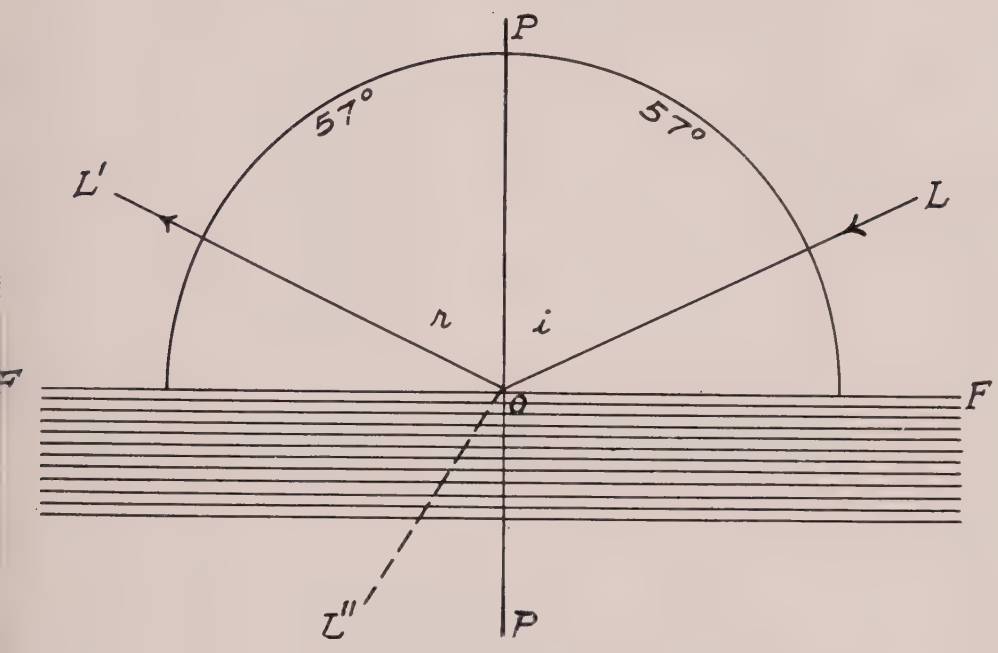



Fig 1.

the obtuse solid angles of the prism and perpendicular to the two modified end faces. The cut or ground surfaces are then polished and cemented together with Canada balsam. The long sides of the prism thus obtained are next blackened and the prism mounted by means of cork or wax in a metal tube. Such a prism is known as a Nicol prism. (Fig. 3.)

Let AFCE represent a principal section of the Nicol prism. A beam of light entering the prism parallel to the long side is resolved into two component rays. One is the ordinary ray, TRO, which is the component most refracted, and it meets the balsam film, EF, at such an angle that it is completely reflected to the side of the prism where it is absorbed by the black coating. The other is the extraordinary ray which is less reflected, and, passing through the film of balsam, emerges in a polarized condition from the end surfaces of the Nicol prism at the point P (Fig. 4). Light in such a condition is said to be plane-polarized.

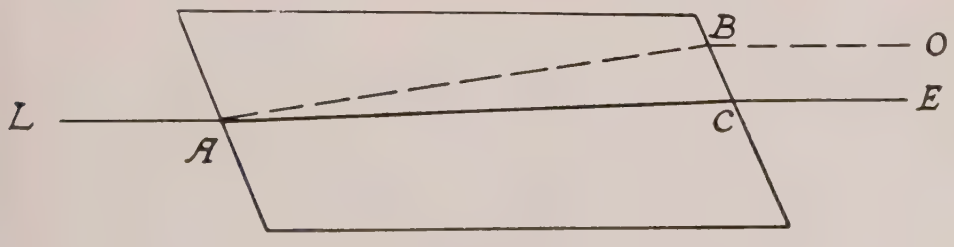



Fig. 2.

Looking through two Nicol prisms at any course of light, holding the prisms in such a way that the light will pass through each successively, and revolving one slowly on its long axis, it will be noticed that the light seen through the prisms varies in intensity as the prism turns. At certain points in the revolution of the prisms, 180 degrees apart, no light passes; while at exactly midway between these positions (90 degrees from them), the most light is seen. As one prism is revolved the light increases up to a maximum, and then decreases until a point of total extinction is reached. Consequently the amount of light passing

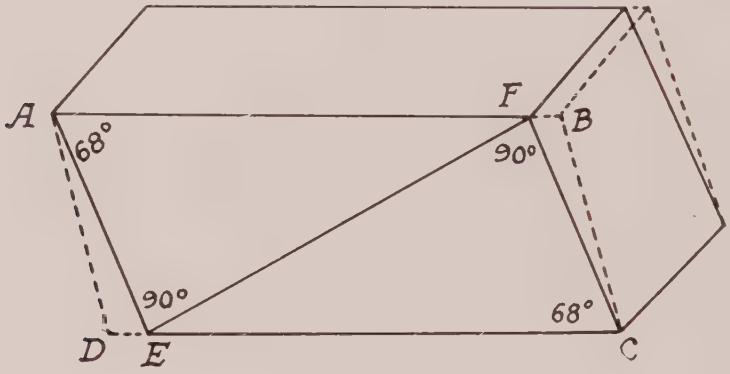



Fig. 3.

through such a combination of Nicol prisms depends on the angle through which one of the prisms is rotated from the positions of maximum or minimum illumination. The relative position of the Nicols showing maximum light intensity is that point of rotation when the rhomboids of the end faces are parallel, each edge of the end face of one prism to the corresponding edge of the other prism. When one of the Nicols is then rotated to a position 90 degrees from this, no light passes and the field is dark. In the first case the Nicol prisms are said to be parallel and in the second case they are said to be crossed.

If the combination of prisms as just described is held in a suitable apparatus, one prism being fixed and the other capable of rotation, a measuring device can be attached to the rotating prism and these phases of light intensity can then be referred to points on a scale. Such an instrument is called a polariscope and can be utilized in sugar analysis. A sugar solution placed between the prisms in such

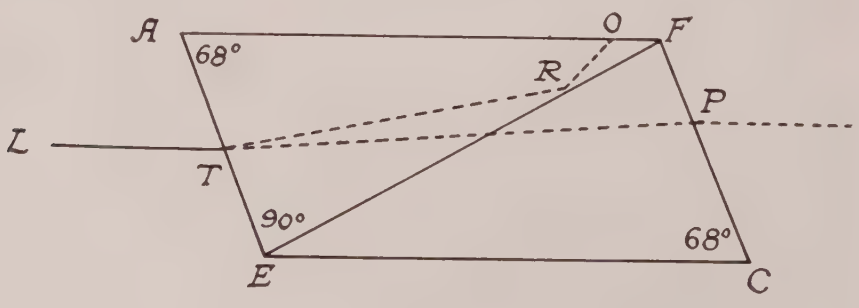



Fig. 4.

a way that the light passes through it in its travel between the prisms, affects the intensity of the light so that it is necessary to rotate the movable prism to restore the light effect shown by the polariscope previous to the insertion of the solution. The magnitude of the angle through which the prism must be rotated to restore the original light effect is found to depend directly on the concentration of the sugar solution and, hence, can be taken as a measure of the sugar itself.

Such a combination of two Nicol prisms constitutes the essential feature of every polariscope. The fixed prism is called the polarizer and the movable one the analyzer.

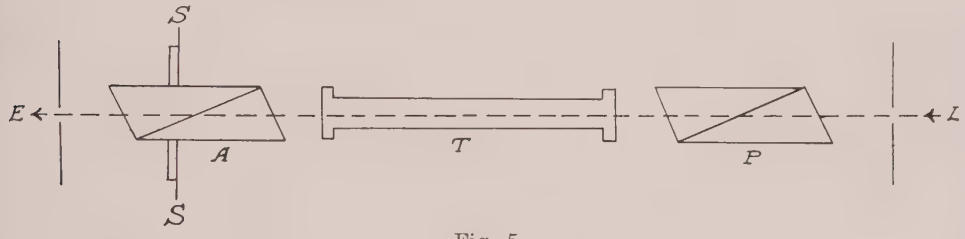



Fig. 5.

The construction and principle of the simplest form of polariscope can be seen by means of a simple diagram (Fig. 5). P is the polarizer, consisting of a stationary Nicol; and A is the analyzer, consisting of a movable Nicol mounted in a revolving sleeve. The angular rotation of A is measured upon a graduated scale, S. L is a source monochromatic light which passes through the instrument to the eye of the observer at E. If the Nicol A is crossed with respect to the Nicol P, the point of extinction of light will then mark the zero point on the scale, S. If now a tube, T, filled with a solution of sucrose is placed between P and A, the plane of polarized light coming from P will be rotated from its original position and the light will be no longer entirely extinguished in A. By rotating A the point of extinction is again reached. The angular rotation produced by the solution in T is then determined on the graduated scale. Because the light rays of different wave lengths which make up white light are rotated to different extents by optically active substances (a phenomenon known as rotation dispersion) it is necessary to use a monochromatic light (e. g., a sodium flame) for this type of polariscope.

One of the first polariscopes to be constructed was one made by Biot in 1840. It was of the simple type just described except that it had an adjustable mirror of black glass for the polarizer and a modified prism of calc spar for the analyzer. The essential features of this early instrument are retained in the modern polariscopes, but in a modified form. In the Biot polariscope the point of total extinction of light constituted the end point; but, as experiment with such an instrument will show, it is impossible to determine the exact point of extinction without a large error, that is, the end point is not sharp.

In the various optical devices for producing a more exact end point, much ingenuity has been manifested; as a matter of fact, these devices alone constitute

the essential differences between most of the different makes of modern polariscopes for measuring angular rotation.

In 1844, the Biot instrument was improved by discarding the polarizing mirror and employing a polarizing Nicol, the optical parts being arranged as shown in the preceding chart (Fig. 6). The most important improvement of this instrument was in the end point. Here a vertical, broad, black band in a light field marked the zero point.

Another end point device used in the earlier instruments was the transition tint quartz plate. Sections of quartz cut perpendicular to the optical axis of the crystal have a strong rotatory effect on plane-polarized light when the light passes through parallel to the optical axis, some crystals being dextro-rotatory and others levo-rotatory. The amount of rotation depends on the thickness of the quartz section.

The transition tint plate consists of two plates of quartz of equal thickness, one of which rotates the plane of polarized light to the right and the other to the left. The plates are cemented together at their edges and carefully ground and polished. These are mounted in such a way that each section covers half of the optical field of the polariscope. If such a plate is placed between two parallel Nicol prisms and examined with white light, the light in passing through such a combination is found to be deprived of its yellow rays, and the field will now show the resulting complementary tint, usually described as a rose violet. If the analyzer is turned to the right or the left the uniform rose color of the plate will change to contrasting tints of red and blue as seen in opposite halves of the field. If a solution of an optically active substance is placed in a tube in front of the plate the uniformity in color of the transition tint will be destroyed, and the two halves of the field will be differently colored. Rotating the analyzer to the point where the transition tint is again produced will give a measure of the angular rotation of the solution.

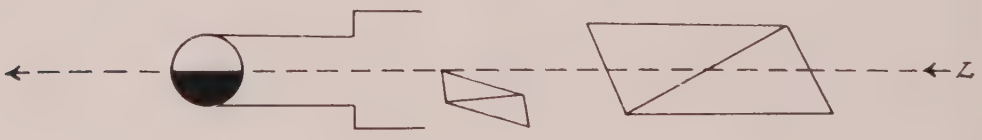


Fig. 6.

In order to overcome the defects of the instrument just described, Jellet constructed the first half-shadow polariscope in 1860. Jellet's half-shadow device consists of a rhombohedron of calc spar with its ends cut square and bisected lengthwise by a plane forming a small angle with the axial plane of the prism; the two halves are then cemented together in reversed position, the result being that the axial planes of each part are no longer parallel but are tilted toward one another at a slight angle. This modified prism is placed between the polarizer and the analyzer with its line of union bisecting the field. In this case rotating the analyzer until it is crossed with the polarizer will not produce total extinction, but a uniform shadow.

The Jellet prism was further modified by Cornu giving what is known as the Jellet-Cornu prism. This was made by bisecting a Nicol prism lengthwise by a plane passing through the shorter diagonal of the end face. A small wedge-shaped section was then removed from each cut surface and the two halves reunited. This split prism combines the effect of an ordinary Nicol and a Jellet prism. The removal of the two wedge-shaped sections causes a tilting of the polarizing planes of the two halves of the prism so that they make an angle of about 175 degrees with each other.

The modified prism is used as a polarizer and is mounted in the polariscope, with a diaphragm having a circular opening between it and the analyzer, in such a way that the opening is bisected vertically by the line of the joint of the two halves of the prism. If the analyzer is turned to a position which would give the total extinction for an instrument fitted with an ordinary Nicol for a polarizer, the field made by the diaphragm opening will not be black in this case, but faintly and evenly illuminated, appearing as a luminous disk. The slightest rotation of the analyzer from this position will produce a shading in one or the other half of the field.

The Lippich half-shadow polariscope uses a small Nicol or "half-prism" for its shadow device. This small Nicol is placed between the polarizer and the analyzer, close to the polarizer, in such a position that it covers half of the field. The polarizer is mounted in such a manner that its plane of polarization makes a slight angle with that of the small Nicol.

The value of the polariscope for the determination of sucrose was quickly recognized in commercial work, and instruments were specially designed to reveal the sugar content of industrial products by a simple and more direct way than by the use of the ordinary polariscope. Such instruments are known as saccharimeters and have scales graduated in divisions expressing percentage by weight of sucrose instead of angular degrees.

In commercial work, where many rapid polarizations have to be made, sodium light is inconvenient to maintain and trying on the eyesight; and, owing to the unequal rotation dispersion of light rays of different wave lengths by optically

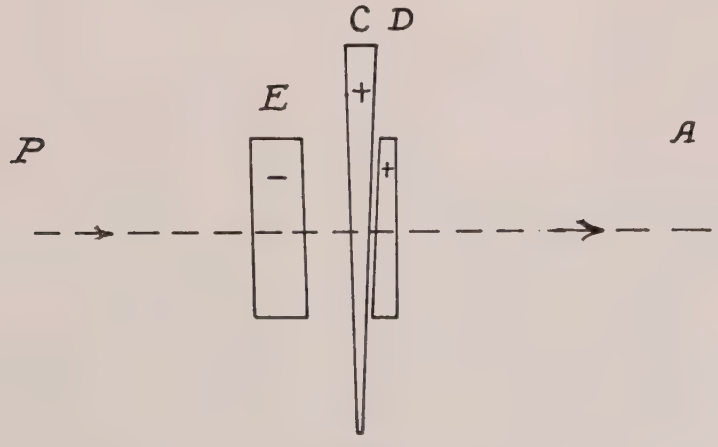



Fig. 7.

active substances, it is not feasible to employ a saccharimeter with a rotating analyzer if the light used is white or compound in nature.

The problem of devising a saccharimeter for use with ordinary lamp or day light was solved in a most ingenious manner by the quartz-wedge compensator, which was invented in 1848 by the French physicist Soleil, who found that the rotary effect of sugar solutions could be exactly neutralized by a plate of optically active quartz of the proper rotation and thickness.

In a quartz-wedge saccharimeter the polarizer and analyzer are both stationary. The rotation of the solution is measured by shifting a wedge of optically active quartz between the sugar solution and the analyzer until the rotation of the wedge system at a certain thickness exactly neutralizes or compensates the rotation of the sugar solution. By means of a scale attached to the quartz-wedge the rotation of the sugar solution is given in per cent.

The selection of quartz for compensation is based upon the fact that it has almost the same rotation dispersion as aqueous solutions of sucrose, but in the opposite direction; that is, a section of optically active quartz and a sucrose solution of equal rotation for light of one wave length will have very nearly equal rotations for light of all other wave-lengths. The small disturbances due to the light difference in rotation dispersion between sugars and quartz may be removed by means of a light filter.

The quartz wedges used in the construction of saccharimeters are cut perpendicular to the optical axis of the quartz crystal; they may be either of dextro- or levo-rotatory quartz, the method of mounting the wedge depending upon the character of the rotation. This can be seen by reference to a diagram (Fig. 7).

PA represents the passage of light through the instrument along its axis, the analyzer being at A and the polarizer at P. C and D are two wedges of right rotating quartz which are movable by being slid past each other in a direction at right angles to the axis of the instrument. Together these two wedges make a section, the thickness of which can be changed readily by moving one or both of the wedges. E is a section of left-rotating quartz. When the combined thickness of C and D equal that of E, the opposite rotating effects of the two wedges and the section E balance, and the scale of the saccharimeter attached to the wedges reads zero. If, now, a tube containing a sucrose solution is placed in the instrument between the polarizer and the compensator, it will be necessary to decrease the thickness of the right-rotating section made by the wedges by sliding them by each other outward till the left rotatory effect of the section E balances the combined effect of C, D, and the sucrose solution. From the scale the percentage of sucrose or the percentage polarization may then be read directly.

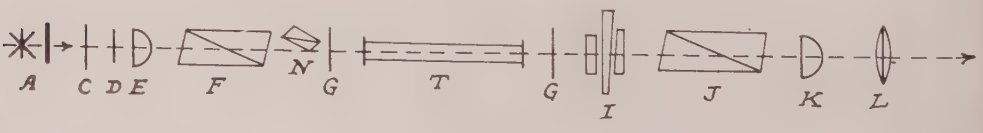



Fig. 8

The final diagram will give some idea as to the arrangement of the various parts of the modern saccharimeter (Fig. 8).

A, is the source of light.
C, a cover glass.
D, a light filter.
E, a condensing lens.
F, the polarizer.
N, the end point device, a small Nicol.
G, splash glasses.
T, a tube for sugar solutions.
I, a quartz-wedge compensator.
J, the analyzer.
K, L, lenses of the telescope.

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# Mill and Boiling House Machinery*

By J. Lewis Renton

## Multiple Knife Sets

Quite an interest is being taken just now in improving the knife sets for preparing the cane for crushing. Aside from the set with only a few knives attached, which can be considered a leveller, the multiple knife set is an aid in extraction and increased capacity for the same reasons that the shredder is. The shredder is more thorough and, therefore, the results are more apparent.

Mr. Meinecke was probably the originator of the multiple knife sets and he now offers an improvement on his original design. The heavy blade holders now used do away with breakage, as the holders can be made of a very tough steel instead of a tool steel which is more or less brittle. The blades are small, cheap, reversible, easily replaced, and on account of their size and support, can be made of good steel and properly hardened.

Messrs. Hind, Hall and Kopke, have gone a step further with their patented knife set and inserted renewable blades. These blades are revolved by removing bolts and changing the blade a quarter turn to a new cutting edge. The improvements claimed for this design over the original Hind hubless revolving knives are as follows:

1. The cutting edge can be renewed without removing the blade from the shaft.
2. Shaft can be revolved in either direction without changing the blade.
3. The flywheel effect of this design is much greater than in any knife arrangement where the knife comes to a point at its outer end.

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* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

4. The cutting edge presented by the disc is very effective; it has a sliding cutting action, as the edge in contact with the cane is the outer extremity of the knife.

5. The construction of the improved knife is much stronger than the original blade.

6. These blades can be used interchangeably with the old type of Hind hubless blade.

W. A. Ramsay offers an improvement of the swinging type of knife set presented by him some time ago. This set retains all of the advantages claimed for the previous design and now adds simplicity of construction in its manufacture. No knife hubs or holders are necessary, merely doing the necessary drilling and tapping to a length of square shaft, the ends, of course, being turned for journals. The swinging feature prevents breakage by swinging away from obstructions and centrifugal force, and at other times holds the knives at right angle to shaft.

Anyone using the multiple knife sets soon observes that practically all of the wear comes on the three or four inches comprising the tip of the blade. At Ewa, the old Meinecke principle has been retained. The hubs have been increased in diameter to reduce the knife overhang and the knives shortened a corresponding amount while increasing the width of the blade from 4½ to 6 inches. This makes a very rugged blade, but is subject to some breakage.

A. Anderson, of Papaikou, is using very hot water from his boiler feed line to wash down with, every six hours, in and around the mills, and reports very good results. Ewa installed an all-metal juice strainer a year ago, and using this strainer with hot water for washing down is getting results. The hot water is procured by running tap water through a discarded high pressure injector. Mr. McCleery stated that the acidity tests throughout the mill trains showed a big improvement and he was of the opinion that a strong force of good hot water was the best method yet developed to hold this loss in check.

## Lubricators

One often wonders, when steam cylinder lubrication and oil in boilers are discussed, why more thought is not given to force feed cylinder oil lubricators. In one case, it was found that the heater pump was using as much cylinder oil as the main mill engine, both being equipped with hydrostatic lubricators. This is not to be wondered at when it is realized that the main engine usually has a competent mechanic in charge who is responsible for the oil used, while the heater pump is fed cylinder oil as fast as the container becomes empty, usually by someone snatching a minute or so from the scales or settling tanks to do it.

Anyone who has tried setting hydrostatic lubricators appreciates the difficulties. If the night is cool, the oil becomes more viscous and the flow is less, no matter at what temperature the oil was put into the lubricator. If you spend a week adjusting it, the chances are that if you came around a week later, the lubricator would be out of adjustment.

A satisfactory force feed lubricator can be purchased for about double the price of a hydrostatic lubricator, or for $22.50, to be exact. They will save enough oil to pay for themselves. Also, the less cylinder oil used means just

that much less oil to keep out of the boilers. This is probably the most important consideration of all.

Some of the good points of a force feed lubricator are:

1. The oil is fed in small increments, resulting in a slow change, if desired. They are also capable of close adjustment.

2. The lubricator, when once set, is not apt to be altered, as tools are necessary.

3. The amount of oil forced into the cylinder is in proportion to the speed of the apparatus.

4. The flow stops automatically when the piece of apparatus stops.

## Elimination of Oil in Boilers

George Duncan, of Olaa, has contributed the following:

This is a subject which has received quite a little attention in several sugar factories throughout the Territory within the last few years, more especially since the inauguration of the Bureau of Boiler Inspection by the Hawaiian Sugar Planters' Association. This does not mean that the evil did not exist previous to that time, but simply that more publicity and attention have been given it since being brought to the notice of the various mill employees by the boiler inspectors.

The danger of allowing oil to enter the boilers is realized by nearly everyone, yet there are a few, who for some reason or another, will not sanction the purchase of the necessary apparatus for its elimination. Perhaps these few cannot be altogether blamed, in a way; it may be that those whose duty it is to make the recommendation have failed to do so, either through ignorance of the existing danger, or perhaps on account of there being installed already, some antiquated arrangement which does not do the work.

The cost of the necessary apparatus for the successful elimination of oil from boilers is infinitesimal when compared with the cost of repairs to them due to the presence of oil. When oily feed water is used, the oil adheres to the heating surface and forms a coating. Oil being a poor conductor of heat, the coating acts as an insulator and reduces the rate of transmission of heat. When the boilers are being worked at or near their capacity, overheating of the heating surfaces takes place, with consequent bagging and possible rupture of the tubes and plates, which might cause a disastrous explosion.

Different methods for extracting the oil from the feed water are used in the various factories. Some separate it from the steam before it goes to the evaporators, vacuum pans, etc.; some attempt to remove it from the feed water after leaving the hot-well; and others make little or no attempt to remove it at all.

As almost all of the exhaust steam is used in the heating and boiling of the juices in sugar factories, the logical method for the removal of the oil would therefore be the first named one, i. e., separating it from the steam before reaching the various boiling apparatus. It is just as bad having the heating surfaces of the tubes in an evaporater covered with oil as it is in a boiler, the only difference being the loss in heat transmission in the evaporator and the consequent lowering in efficiency of the apparatus.

There are various types of separators on the market for separating the oil from the steam, but a very efficient type is one that is built locally for this purpose. It consists of a steel drum closed at both ends, about 3′ 6″ diameter and about 8′ 0″ long. The drum lies horizontally and there are two openings in it, both the same size as the exhaust pipe. The inlet opening is in the center of one of the heads, the outlet being at the other end but through the shell, on the top. Inside the drum is a deeply ribbed cast-iron plate, placed 6″ in front of the inlet. This plate is open at the sides and bottom, but closed at the top. The entering exhaust steam impinges against the ribbed plate, then passes to the outlet, through the openings between the shell and sides of the plate. The ribs of the plate, being

at right angles to the direction of flow of the steam in its passage from the inlet to the openings between the shell and plate, act as retainers for the oil collecting on the plate, until it drains to the bottom of the drum. From there it is drained off by a 2″ pipe in the bottom of the drum at the outlet end. This apparatus does all that is claimed for it.

The method of extracting the oil from the boiler feed water after leaving the hot-well is done by feed water filters. There are various types, but two seem to predominate; one in which excelsior is used as the filtering medium, the other in which Terry cloth or Turkish towelling is used. They may do the work that is claimed for them, but as the filtering medium has to be removed and cleaned at least once a week, the cost of their operation is high in comparison with the steam separator, which requires no attention whatsoever except to see that the drain pipe is kept open.

It has been observed at the cleaning of a feed water filter, connected to the surface condenser of a steam engine, that not 20 per cent of the cylinder oil fed to the engine was to be found on the filtering cloth. It must therefore be assumed that a large portion of the oil found its way through the cloth and incidentally into the boilers.

There is no doubt that the ideal installation would be an oil separator, placed ahead of the boiling and evaporating apparatus, and a feed water filter in the feed line. In that case it would be practically impossible for any oil to ever find its way into the boilers.

The quality of cylinder oil to be used in a sugar factory is an important question. It is false economy to use cheap brands. As has been proved, more than 50 per cent saving in the consumption of oil can be obtained by the use of a high grade quality, than can be by the use of one at half that price. Why not use the expensive oil and give the separators and filters less work, when the yearly cylinder oil expense can be kept at or near the same amount as when the consumption of the cheap oil is more than double that of the former?

A. W. Dunn, of Honomu, describes the method of eliminating oil at Honomu Sugar Company, through the employment of a counter current surface condenser, as follows:

According to the method now generally practiced in sugar factories, the exhaust steam from all the various engines and pumps is utilized for boiling sugars and sugar juices. The condensate from the various elements of sugar-making apparatus is drained into a hot-well and thence fed into the steam boilers. This method is objectionable for the reason that the exhaust steam from the various engines and pumps carries more or less cylinder oils, consequently the condensates from the various pre-evaporators, juice heaters, and vacuum pans (which are operated by exhaust steam) are impregnated with cylinder oils, which enter the boilers.

The presence of oil in boilers renders same dangerous, reduces boiler efficiency and causes leaky boilers, entailing costly repairs.

The system now in operation at Honomu prevents lubricating oils from entering boilers and keeps the heating surfaces free from oil, as the greasy condensates are taken into a condenser and utilized as heating agents to raise the temperature of the fresh water supply or "make-up."

From the foregoing it will be seen that there has been provided a very simple arrangement whereby oily condensates are exchanged for an uncontaminated feed water supply without material loss of temperature in the feed water entering boilers.

This system has been in operation at Honomu mill for the past seven months, and, at the close of the grinding season, the boiler inspector reported boilers free from oil.

## Boiler Room

*Boiler Installations:* There have been so many excellent papers presented on the Boiler Room that it is difficult to present a paper. A. G. Budge's (1) paper on Boiler Room Equipment and Operation covers the requirements of a perfect steam boiler and the selection and operation of boilers.

"Practical methods of comparing the results obtained when burning bagasse as fuel," by Mr. Horace Johnson (2) is worth studying.

Leaving these subjects out, it will be endeavored here to study the design of boiler installations and the factors governing the relation of the boiler to the grate, furnace and stack.

The function of the grate and furnace is to completely consume the combustible with a minimum of excess air, and be of such a size that enough hot gases are passed on to the boiler to produce the rating desired. The size of the boiler, then, should determine the grate area, which in turn determines the furnace volume. The draft will vary these considerations, but will, at present, be assumed to be uniform.

*Boilers:* It would seem logical, then, to study the factors covering the size and rating of boilers.

There always has been and still is considerable discussion on the question of rating for a boiler. The writer has always taken ten square feet of boiler heating surface for one boiler horse power. This is done for two reasons. First, it gives the approximate heating surface immediately by adding one cipher; and the heating surface is a reliable factor of size. Second, it has been found that for most boilers the best results are obtained with an evaporation of about 3.5 pounds of water from and at 212° F. per square foot of heating surface per hour, which corresponds very closely to 10 square feet of heating surface per boiler horse power.

The rating has nothing to do with developed horse power, as an evaporation of 10 pounds of water per square foot of heating surface per hour can be attained, which will result in about 3½ square feet of heating surface per boiler horse power. It is also possible to go to the other extreme and have excessive heating surface. This is sometimes advisable where considerations governing the installation make it advisable to combine the heating surface of a boiler and economizer in one unit, this unit performing the function of both.

It is customary to assume a uniform heat transmission for the entire exposed heating surface. Each square foot of heating surface is then capable of transmitting a certain amount of heat, depending on the conductivity of the material, the character of the surface, the temperature difference between the gases and the water, the location and arrangement of the tubes, the density of the air, the velocity of the gas, and the time allowed for transmission of the heat.

Noel Deerr (3) observed in this connection:

> I have always held that economy in combustion is obtained in the furnace and that the boiler plays a comparatively small part in fuel economy. Water tube boilers are, however, made in units of much larger dimensions than the return tubular boilers, hence for a given heating surface in the boiler there is less exposed radiating surface with the water tube boiler than with the return tubular boiler.

There are two other important considerations in the attainment of rating in a bagasse boiler—as compared with coal and oil-fired boilers—and these are lack of absorption by direct radiation to boiler from the combustion chamber and the lower gas temperatures. In this respect, the bagasse boiler is about in the same class as the wood waste fuel boiler and better off than the waste heat installation.

*Steam,* published by The Babcock & Wilcox Company, informs us as follows:

In direct-fired coal or oil-fired practice, where furnace temperature of from 2,400 to 2,800 degrees are commonly developed, the amount of heat absorbed by direct radiation from the furnace represents a very large percentage of the total heat absorbed by the boiler.

If the results of direct-fired boilers and waste-heat boilers are to be compared from the standpoint of total heat absorbed as measured by steam output, the increased absorption through radiation in the direct-fired boiler must be offset by a corresponding increase in absorption by convection in the waste-heat unit over that absorbed by convection in the direct-fired boiler. For high rates of convection absorption, high rates of heat transfer are essential, and such transfer rates necessitate high gas velocities.

For boilers developing approximate rating in the two classes of work, with waste gas temperature of from 1,200 to 1,300 degrees entering, and the arrangement of direct-fired boiler surface ordinarily found in stoker-fired work, the velocity of gas through the waste-heat unit is probably slightly more than three times that through the direct-fired boiler.

There are tests on record showing waste-heat boilers developing considerably over rating with temperatures of gas at 1700 to 2100° F., which is certainly no better than bagasse boiler work.

This would lead one to believe that the so-called high type of boiler, or one that is narrow for its particular H. P. rating, would lend itself to our conditions on account of the high velocity of gases. This would be so provided that the necessary grate area could be accommodated without too much expense or too much lost heat by increased radiating surface.

The following table is presented to show the differences that probably exist in bagasse-fired and coal-fired boilers:

TABLE 1

| | Coal | Bagasse |
|---|---|---|
| B. T. U. per pound of dry fuel | 12,825 | 8,350 |
| B. T. U. per pound of fuel as burnt | 12,248 | 5,010 |
| B. T. U. lost in flue gases at 500° F | 2,408 | 1,635 |
| B. T. U. available for useful work | 9,840 | 3,375 |
| Temperature of combustion | 2,746 | 2,156 |
| Cubic feet of flue gases 500° F | 459 | 198 |
| Pounds bagasse equal to pound of coal | ..... | 2.92 |
| Cubic feet of flue gases from 2.92 pounds bagasse | ..... | 578 |

This shows that it takes 2.92 pounds of bagasse to equal a pound of coal—the temperature of combustion is lower and the volume of gases is 39 per cent greater when considering the same available heat.

It is considered good practice to assume 5 pounds of coal per B. H. P. at 150 per cent rating; this gives us 3.33 pounds per B. H. P. This corresponds to 9.73 (3.33 x 2.92) pounds of bagasse per B. H. P. at rating. This figure of 9.73 checks very closely with actual experiments in Hawaii.

As far, then, as boilers themselves are concerned, there is no valid reason why rating, or more than rating, can not be attained, provided the necessary heat units are supplied to the boiler from the furnace.

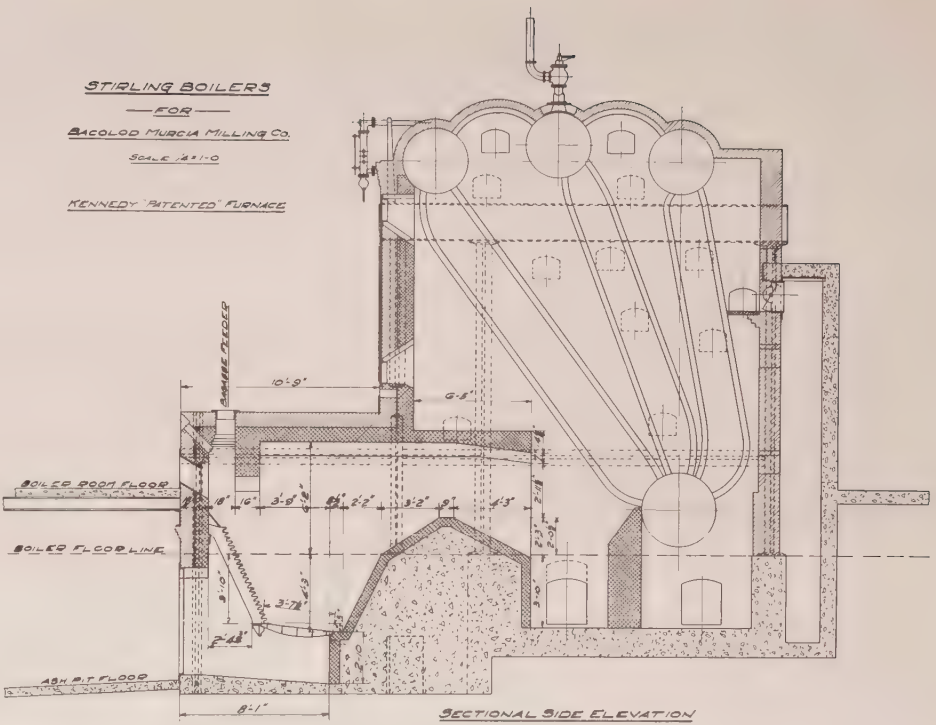
STIRLING BOILERS

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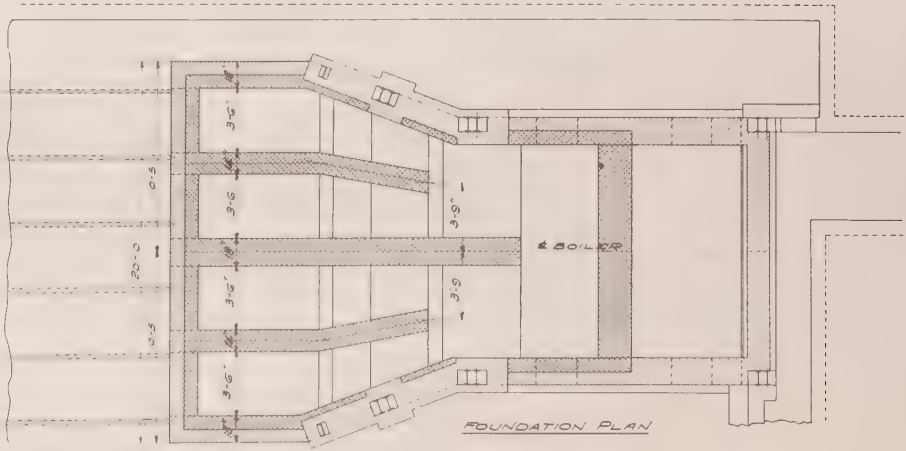
BACOLOD MURCIA MILLING CO.

SCALE 1/4"=1'-0

KENNEDY "PATENTED" FURNACE




SECTIONAL SIDE ELEVATION




FOUNDATION PLAN

## Grates

The function of the grate is to furnish, with as little loss as possible, sufficient combustion to furnish the required hot gases to attain the boiler rating, previously decided upon, as desirable.

The amount of draft has quite an effect on the amount of bagasse that can be burnt per square foot of grate area per hour.

Oahu Sugar Company, Ltd., can get 125 to 150 rating out of their boilers with .077 square foot of grate per B. H. P., while at Ewa, we employ .215 square foot for the same results and the new boiler installations at Waimanalo have about .170.

It would seem reasonable to suppose that the amount of bagasse burnt per square foot of heating surface per hour in all three cases should be about the same. We can assume that one pound of bagasse is required per S. F. H. S. per hour.

This checks very closely with the figure derived in the previous computations, which is .975 pound per S. F. H. S. (or 9.75 pounds per B. H. P.).

The pounds of bagasse per square foot of grate surface per hour at 125 per cent boiler rating for the three installations mentioned are:

Oahu—163 Waimanalo—75 Ewa—58

The Honolulu Iron Works Company have been kind enough to furnish the following information on 14 Stirling boiler installations of their design. Assuming 100 per cent rating, and one pound of bagasse per square foot heating surface, the pounds of bagasse burnt per square foot of grate area per hour vary from 70 to 96, with an average of 81. Assuming arbitrary ratings from 90 to 120 of full rating load, we find:

| | | | | |
|---|---|---|---|---|
| Per cent rating..... | 90 | 100 | 110 | 120 |
| Pounds bagasse per S. F. G. A. per hour..... | 73 | 81 | 89 | 99 |

Admitting that these are all assumptions, they are not very far off, as there is no logical reason why the amount of bagasse burnt per square foot of boiler heating surface per hour should vary greatly. If there is any great variation, it is an indication that the furnace design is faulty, provided the moisture in bagasse is fairly uniform.

The deduction then is, that for the amount of draft encountered on most plantations, the pounds of bagasse per square foot of grate area for Stirling boilers is about 75 pounds instead of 100 to 125 as usually understood.

It is interesting to note in this connection, that the Kennedy Patent Furnace increased the output of the boiler considerably above rating. This was an increase in rate area and furnace volume only, and neglecting the furnace would tend to indicate that increased grate surface alone was what was needed. Since the draft was not changed and the flues and stack were able to handle the increased volume of gases evolved, this would eliminate draft as the important factor and again stress the importance of grate area. The furnaces for these boilers were originally laid out after the Hawaiian practice, and following in our footsteps, failed to develop the rating desired. Assuming 1.2 pounds bagasse per S. F. H. S. per hour, we have the following pounds of bagasse per S. F. G. A.:

100% rating—58 125% rating—72.5 150% rating—87.5 175% rating—99.5

The effect of furnace changes was left out of our consideration as the changes did not alter the ratio of furnace volume to grate area to any appreciable extent.

It is hoped that there will be some discussion on this point of the desirable amount of bagasse to burn per square foot of grate area. Consideration of draft will be taken up later.

It is believed that, at least for Hawaiian conditions, the step grate has certain advantages over the so-called flat grate of Cuba. One of the very important factors for complete combustion with a minimum of excess air is to bring the combustible, whether in a solid or gaseous state, into intimate contact with the available oxygen in the air drawn into the furnace. It would appear then that the step grate, drawing a good part of the air for supporting combustion through the fuel bed of practically uniform thickness, would have a much better chance for combustion with a minimum of excess air than the furnace with a burning cone of bagasse, and introducing air on all sides of the cone through openings in the furnace, or around the edges of the cone.

The big lumber mills used to dump their wood refuse on flat grates, but are now building elaborate furnaces. They are having just as good results with the step grate as with flat grate construction. (See A. S. M. E. Journal, July, 1925.)

The tendency in the Philippines is to have very steep step grates (about 60° from the horizontal) and install 3- or 4-foot bottom grates. The moisture content of Cuban bagasse is in the neighborhood of 48 to 50 per cent and in the Philippines about 47 per cent. This may have an important bearing on type of grate needed.

## Furnaces

The ideal furnace is that which will completely consume the combustible with the least surplus air. To obtain this result the furnace temperature should be the maximum that can be maintained, and combustion should be complete within the furnace. There is nothing new in this, as A. Gartley, in 1918, pointed out that "for efficient combustion it is essential that a high temperature be obtained in the furnace, that products of combustion have as high a per cent of $CO_2$ as possible, and that the stack temperature be low."

*Complete combustion* with the *least surplus* will give *maximum temperatures* and the nearest approach to the ideal possible. Each of these three main factors has such a bearing on the net result that we will discuss them separately, with respect to their bearing on furnace design.

The maximum temperature that can be maintained in any furnace under present approved furnace construction is about 2200° F. to 2400° F. when loaded to 20 pounds to the square inch. Reducing the allowable load to 10 pounds per square inch will increase the permissible temperature about 200° F. It is necessary to keep down the furnace temperature in coal- and oil-burning furnaces by placing the boiler directly over the burning fuel and letting the boiler absorb some of the heat of combustion by radiation.

With bagasse, this is not necessary. Therefore, any furnace that is so designed that there is no intervening wall between the fuel bed and the boiler is taking

chances, because, if there is a lowering of the temperature below the point where combustion is supported, losses will occur.

The temperature of combustion, for various moisture content of bagasse and variable amounts of excess air, is:

TEMPERATURES OF COMBUSTION

| Excess Air | Per Cent Moisture of Bagasse | | | | | | |
|---|---|---|---|---|---|---|---|
| | 36 | 38 | 40 | 42 | 44 | 46 | 50 |
| 50% | 2756 | 2731 | 2677 | 2621 | 2591 | 2527 | 2436 |
| 75% | 2452 | 2433 | 2366 | 2340 | 2317 | 2263 | 2187 |
| 100% | 2211 | 2196 | 2156 | 2116 | 2097 | 2050 | 1985 |
| 125% | 2013 | 2007 | 1967 | 1931 | 1916 | 1875 | 1819 |

(Assuming 8350 B. T. U. per lb. dry bagasse and 80° F. Room Temp.)

Since 75 to 100 per cent excess air is not considered abnormal, it is evident that there is not much danger of overheating the furnace. It is also usually found that the actual furnace temperature is less than the computed, especially where heat is removed by radiation.

Mr. Kerr (5) took many furnace temperature readings and submitted the following in his general remarks:

| Factory | Average Furnace Temperature | Average Rate of Combustion | Average Evap. per pound Dry Bagasse |
|---|---|---|---|
| A | 1633 | 130 | 4.64 |
| B | 1511 | 90 | 4.10 |
| C | 1420 | 62 | 4.00 |

(Factory "A" had highest $CO_2$ readings.)

These figures are lower than the figures from the above table under 50 per cent moisture. (This is the approximate moisture of Cuba and Louisiana.)

Why there should be so much discrepancy is not known, unless heat is allowed to escape by radiation. One very important point is indicated, though, and that is the benefits of the higher temperatures.

Under a closed furnace and one that is known to be quite hot, there are conditions present that appear as if the fire brick was melted on the furnace surface. I am inclined to believe that this is a chemical action due to the iron and lime in the bagasse and not a temperature action. Calcium and iron are both violent fluxes to fireclay brick made of normal mixtures of oxides of aluminum and silicon. An analysis of furnace ash selected at random by the H. S. P. A. Experiment Station showed 6.43 per cent iron and 6.23 per cent lime.

G. F. Gebhardt states that the temperatures necessary to cause a union of oxygen and fuel are approximately as follows:

Carbon Monoxide—1211° F. Hydrogen—1100° F.

It is very important that the temperature of gases should not be lowered below the point of combustion of carbon monoxide until we are assured that this combustible has been consumed.

This leads us to the consideration of complete combustion. The large lumber companies of the Northwest, realizing the value of waste wood and hog fuel in salable electrical energy, have done extensive research work in furnace development.

Mr. Kerr (5) was not able to draw any conclusive deduction about furnace volumes in his report on account of other variations.

The only dangers then of too large a furnace are radiation and leakage losses.

There is an economical limit to the amount of excess air that should be admitted for combustion. Adding more air will so increase the volume of gases as to incur losses at the expense of complete combustion.

Practically every furnace of fairly large dimensions, designed for bagasse or wood waste fuel, has ports of auxiliary air inlets for the admission of air other than through the fuel bed. Jacobus (7) and Simeral (8) claim "that gases containing excess air will ordinarily mingle more readily with the hotter gases containing unconsumed combustible matter, if they are made to travel over and above the hotter gases within the furnace, as this leads to an eddying action, due to the greater density of the gases containing excess air."

It is interesting to note that this theory has not been put into practice, the engineers probably depending on the shape of the furnace to accomplish the mixing action.

For the nearest approach to the ideal furnace then, the main consideration is the shape of the furnace. It is not sufficient to be large enough. It is more important to have it long enough. This is necessary to allow time for mixing and time for complete combustion after mixing has taken place. The more complete the mixing, the more thorough the combustion, and the less excess air will be required for complete combustion.

The drop nose arch as shown in both wood-burning furnaces is gaining much favor in assisting in the mixing. I would like to see this principle tried out. If applied, this feature would have these advantages:

1. Protect the furnace from radiating heat to boiler and reflect high furnace temperature on fuel bed, producing quick evolution of volatile matter.

2. In conjunction with bridge wall, would impose a barrier to smooth flow of gases, the bridge wall below and the drop nose above, creating an eddying and mixing action aiding in complete combustion with minimum excess air.

3. The bridge wall and drop nose create an actual longer path for gas travel allowing time for complete combustion.

4. The deflecting of the gases down insuring that section "A" will act as part of combustion space.

It is not claimed that this is the only way to accomplish these results. There is room for improvement and some thought along these lines will bring results.

There is a mistaken idea sometimes that flue gas analysis is a measure of furnace efficiency. D. S. Jacobus (7) states as follows:

> The flue gas analyses are not all that govern the efficiency, as much depends on whether or not there is delayed combustion between the boiler tubes. It is all wrong to assume that if two boilers are operating with the same average flue gas analyses and per cent of carbon in the ash, the furnace efficiency is the same in each, as actually there may be a wide difference due to the fact that all of the combustible gases may be consumed in the furnace in one case and not in the other.

It is necessary, then, to properly design our furnaces and control them with $CO_2$ readings.

The important point is to note the direction of flow of the gases. I believe the following rule will cover furnace volume qualifications: Furnace volume shall exclude all volume back of apron arch at bagasse feeder and include all volume following the direction of flow of gases up to a point where gases leave the furnace, or extension thereof, and come in contact with, or approach, the boiler.

## Chimneys

The height and diameter of a chimney depend on the amount of fuel to be burned, its nature, the design of the flue, with its arrangement relative to the boilers, and the altitude above sea level. The last consideration can be neglected as the chimneys here are not at any appreciable altitude.

The method best suited for determining the proper proportion of stack and flues is dependent upon the principle that, if the cross-sectional area of the stack is sufficiently large for the volume of gases to be handled, the intensity of the draft will depend directly upon the height; therefore, the method of procedure is as follows:

1. Select a stack of such height as will produce the draft required by the particular character of the fuel and the amount to be burned per square foot of grate area.

2. Determine the cross-sectional area necessary to handle the gases without undue frictional losses.

It is poor economy to restrict the size of the flue and thus make additional stack height necessary to overcome the added friction. The general practice is to make the flue as large or slightly larger than the stack. A good figure is 20 per cent larger than the stack, and a safe rule is to allow 52 square feet for every 1000 boiler horse power. (This corresponds to about 42 square feet for coal burning practice.)

There are so many variables entering into the figuring of chimney sizes, that empirical formulas, based on experience, have taken the place of theoretical computations. In our case, for instance, not as much draft is desired as in coal burning practice, as there is danger of carrying the fuel off the grate; and yet, for the same heat available for useful work 25 per cent greater volume of gases.

The Honolulu Iron Works recommend about 130 feet above grate for a chimney for bagasse without economizers. This gives us about 0.52 to 0.72 inches of draft developed. This checks fairly closely with replies to G. H. W. Barnhart for his paper on Comparative Data on Factory Equipment, the values ranging from 0.5 to 0.9 inches of water at damper.

At one plantation, in the Philippines, where a 130-foot stack was installed, it was found advisable to increase this by 40 extra feet of height. If we are agreed that 0.7 inch at damper is sufficient to properly burn bagasse, either one of two explanations is possible: the stack was too small in diameter or the grate area was not sufficient. This brings us back to the previous considerations of desirable grate area. Admitting that anyone can increase the rate of combustion by increasing the draft, would it not be better to increase the grate area? (The diameter of the stack would be the same in either case.)

The volume of gases evolved by burning bagasse is easily determined, and it is a simple matter to calculate the diameter, with a fair degree of accuracy, if the horse power developed is known.

The following table was computed from a table which may be found in most handbooks and the following assumptions have been made:

1. Allowance has been made for 125 boiler rating, or 1¼ pounds of bagasse per S. F. H. S. per hour.
2. Height of stack 130 feet above grate.
3. Temperature of flue gases, 500° F.
4. The bagasse moisture .40.
5. The excess air is 100 per cent.

DRAFT IN INCHES OF WATER

| Boiler H. P. Allowing 150% Rating | Diameter of Stack in Feet | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 600 | .55 | .77 | ... | ... | ... | ... | ... | ... | ... |
| 672 | .44 | .73 | .82 | ... | ... | ... | ... | ... | ... |
| 768 | .30 | .68 | .79 | ... | ... | ... | ... | ... | ... |
| 864 | ... | .64 | .78 | .83 | ... | ... | ... | ... | ... |
| 960 | ... | .59 | .75 | .82 | ... | ... | ... | ... | ... |
| 1152 | ... | .46 | .70 | .79 | .83 | ... | ... | ... | ... |
| 1536 | ... | ... | .56 | .73 | .81 | .83 | .85 | ... | ... |
| 1920 | ... | ... | ... | .65 | .77 | .81 | .83 | ... | ... |
| 2400 | ... | ... | ... | .53 | .70 | .78 | .82 | ... | ... |
| 2880 | ... | ... | ... | ... | .62 | .73 | .79 | .82 | .83 |
| 3360 | ... | ... | ... | ... | .52 | .68 | .75 | .81 | .83 |
| 3840 | ... | ... | ... | ... | ... | .62 | .70 | .78 | .81 |
| 4320 | ... | ... | ... | ... | ... | .56 | .69 | .75 | .79 |
| 4800 | ... | ... | ... | ... | ... | ... | .64 | .73 | .78 |

| | | |
|---|---|---|
| For 350° F | deduct | .16 |
| " 400° F | " | .10 |
| " 450° F | " | .05 |
| " 550° F | Add | .05 |
| " 600° F | " | .09 |
| " 650° F | " | .12 |
| " 700° F | " | .16 |
| " 750° F | " | .19 |

The following table shows the effect on chimney of varying the bagasse moisture and excess air. The factor given is to be multiplied into the boiler horse power rating in the previous table for corrected rating:

FACTOR FOR HORSE POWER RATING IN TABLE OF AVAILABLE DRAFT FOR 130-FOOT STACK FOR VARYING MOISTURE CONTENT AND EXCESS AIR

| Excess Air | Moisture Content | | | | | |
|---|---|---|---|---|---|---|
| | 36 | 38 | 40 | 42 | 44 | 46 |
| 50% | 1.38 | 1.36 | 1.33 | 1.31 | 1.28 | 1.24 |
| 75% | 1.19 | 1.17 | 1.15 | 1.12 | 1.10 | 1.07 |
| 100% | 1.04 | 1.02 | 1.00 | .98 | .96 | .94 |
| 125% | .83 | .82 | .80 | .79 | .77 | .75 |

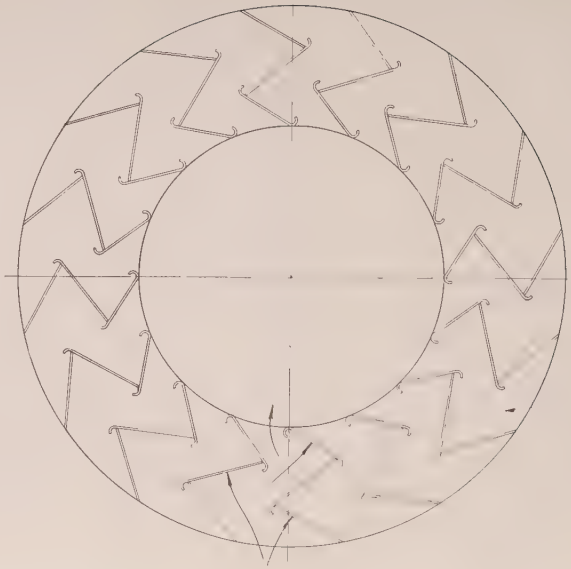
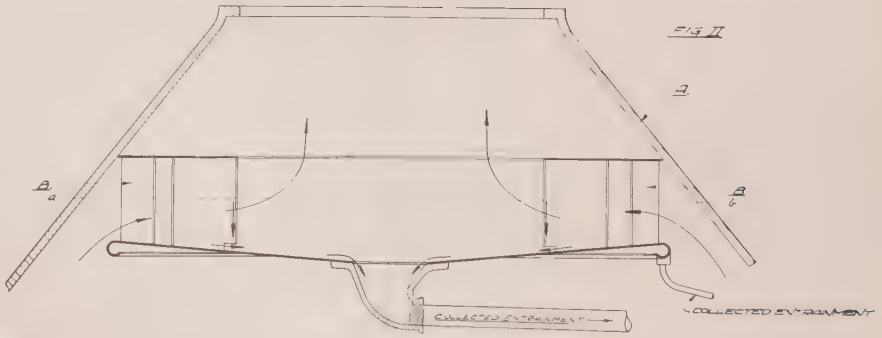



FIG I

B.

FIG II

A.




The Lawrence Improved Trap

REPRESENTATIVE BOILER INSTALLATIONS

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Boiler No. | | Type of Boiler | Boiler Horse Power Rating HP | Square Feet of Grate Area GA | Cubic Feet of Furnace Volume FV | Grate Area Factor GAx100 / HP | Furnace Volume Factor FVx100 / HP | Combustion Time in Seconds |
| 1. | Hawaii—older setting | Ret. Tub. | 254 | 41 | 199 | 16.1 | 78 | 1.13 |
| 2. | | B. & W. | 396 | 85 | 480 | 21.5 | 121 | 1.16 |
| 3. | | Stirling | 411 | 44 | 218 | 10.7 | 53 | 1.11 |
| 4. | | Stirling | 493 | 38 | 420 | 7.7 | 85 | 2.48 |
| 5. | | Stirling | 603 | 54 | 590 | 8.9 | 98 | 2.46 |
| 6. | Hawaii—newer setting | B. & W. | 396 | 64 | 674 | 16.2 | 170 | 2.36 |
| 7. | | Stirling | 545 | 101 | 1161 | 18.5 | 213 | 2.58 |
| 8. | | Stirling | 391 | 66.5 | 820 | 17.0 | 210 | 2.90 |
| 9. | Philippine (Kennedy) | Stirling | 630 | 130 | 1045 | 20.6 | 166 | 1.80 |
| 10. | Cuba | Ret. Tub. | 254 | (41) | 1094 | 16.1 | 430 | 6.00 |
| 11. | | Stirling | 603 | (58) | 973 | 9.6 | 161 | 3.76 |

The factor 100 used in computing columns 7 and 8 is used for simplicity only.

The last column shows the time in seconds for a complete change of volume of gases in the furnace and is added to indicate the rapidity with which combustion is taking place. It is figured at 81 pounds of bagasse per square foot of grate area, and in some cases it is known that this figure is greatly exceeded.

C. H. Courser, in *Power*, of November 20, 1923, has the following to say, which might be of interest to some of the engineers:

### FLUE GAS THERMOMETER AS SUBSTITUTE FOR $CO_2$ INSTRUMENT

It is probably the wish of most engineers to have a recording $CO_2$ instrument, with which to check boiler performance, but sometimes the cost makes it hard to get the approval of the powers that be.

We have been trying out recording flue gas thermometers and find that results in small plants compare quite favorably with $CO_2$ instruments. We know that with a clean boiler, good baffles and settings, and with 13 or less per cent $CO_2$, the excess air is cut to a minimum and the temperature of the flue gas will be low; that is, from 100 to 200° F. above the temperature of the water in the boiler, depending on the load. The temperature of the water in the boiler can be found from the steam tables. At normal rating there should not be over 150° difference. If we admit an excess of air, the flue gas temperature will immediately rise, and the more the excess, the higher it will go.

With a long distance recording thermometer installed at about one-third the cost of a $CO_2$ instrument, we have a fairly good check on the condition of the boilers and how the firemen handle the fires. If the temperature goes up, there is probably one of three things the matter: an excess of air, dirty tubes, or leaky baffles. The $CO_2$ instrument might show good $CO_2$ and still the tubes could be dirty or the boilers have leaky baffles. Of course, for best results, the instrument should be placed where the firemen can see it at all times. We use the recording thermometer on both oil and coal fired boilers and get equally good results.

## Boiling House

Wm. Kruse, of Kekaha, reports:

The Western States Machine Company Robert Gibson self-discharging centrifugals with all latest labor equipment are working very satisfactorily. The four machines dry

700 cubic feet massecuite in 1 hour and 10 minutes. It took the American flat bottom machines, built in 1922, from 2 to 2½ hours to do the same work, with moisture in the sugar about the same.

We have run the new machines 925 r. p. m. and expect to increase speed to 1,000 r. p. m. during 1925 repair season. We are fully convinced that these machines will dry from 200 to 225 tons sugar in 24 hours without ever working the four machine men, which would make 50 tons per man in 24 hours.

Arthur F. Ewart and Seymour Terry have made improvements in entrainment traps for which they seek patent protection.

This trap is placed in the upper part of an evaporator or vacuum pan cell in which the evaporation or vapor production takes place.

To trap particles of liquor that are projected up from the boiling mass and are carried along with the vapors, numerous devices are employed.

With the employment of this device two important requirements of an entrainment trap are fulfilled: (1) The complete impingement of entrained particles of liquor, that move at considerable speed along with vapors. (2) The collecting of the impinged and precipitated particles of liquor and conducting them away from the path of the moving vapors back to their source.

The novelty of this design lies in the zigzag shape of the baffle vanes and the arrangement of plates and channels for centrally collecting and returning the trapped liquor.

## Water Cooled Crystallizers

An improvement which has been worked out by Messrs. Ernest W. Kopke, William Wyllie, and H. S. Walker in the Philippines, is a crystallizer cooler for low grade massecuites. This consists of a set of cooling coils spaced across the crystallizer in such a way that each coil takes care of a definite volume of massecuite and does not interfere with the motion of the stirring arms. The original stirring arms are utilized, the cross pieces only being removed. Massecuites have been cooled from 160° to 100° F. in 36 hours, with cooling water at 86° F., without the formation of any false grain. This is particularly advantageous where it is desirable to carry a small stock in process, since one water cooled crystallizer will do the work of more than two air cooled crystallizers, and the cooling equipment, including royalties, can be put in for less than half the cost of a new crystallizer. The idea of water cooling, of course, is not new, but the arrangement of stationary coils has a great many advantages which we in Hawaii might try out.

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7—D. S. Jabocus—Boiler and furnace economy, A. S. M. E. Trans., No. 43, p. 883.
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# Camp Improvements*

By Donald S. Bowman

The improvement of morale and health is largely conditioned by camp improvements. This is now fully realized by plantation owners and managers. There can be no other deduction when one is familiar with the rapid progress being made in rehabilitation and new construction work on the sugar plantations throughout the Islands.

For several years past, the average expenditures for construction and maintenance of camp dwellings have been over $1,400,000 per year, while the amount expended for medical service and sanitation has been about $640,000 per year. Aside from these sums, large amounts have been invested in roads, domestic water supplies, etc., all of which have their effect on morale and sanitation.

## First Sugar Camps

The first sugar plantation was started in Manoa Valley in 1825. This, however, failed, and the next attempt was made at Koloa, Kauai, in 1835. This plantation has been operated continuously since then. In 1835, aside from a small camp near the Koloa Mill, the laborers, native Hawaiians, were housed in their own villages.

It is most interesting for one concerned with housing problems and camp improvements to study the housing of the primitive peoples of the world, and to note that it is evident that the Hawaiians at the time of Vancouver and other early voyagers, were better housed and more domesticated than any of the other aboriginal peoples. From a description of their housing, obtained from articles written in Vancouver's time and later, we learn that they were not only well and completely housed, but that their villages were arranged according to a comprehensive plan that corresponds today with what we know as city or village planning.

The principal houses were located in close proximity to the heiaus in the larger permanent villages. Separate dwellings housed the chiefs, the kahunas, the retainers, the women, and the men. The dwellings of these early Hawaiians varied according to the rank and means of the owner, the houses of the field laborers or fishermen being huts 8 x 10 feet to houses 12 x 20 feet, while the houses of the chiefs varied from 40 to 70 feet in length. Except in the case of a chief, each man built his own house. When a chief wanted a house, all those who held land under him built it. The houses were well built and thatched and would last from five to ten years. They were simply furnished with lauhala mats, baskets, gourds, calabashes, wooden dishes, tapas, etc.

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Evidence of their knowledge of good sanitary practice was found in the disposal of their refuse, in the segregation of the sick, in the use of the spitoon, etc. They evidently led a sanitary, simple, and contented life.

We find that they did not take kindly to plantation work and that only a small percentage could be induced to work in the fields. This necessitated the importation of labor, and in 1852 the first Chinese were imported. From that date, the plantation camps were started. In 1868, the first Japanese laborers arrived, followed in 1877 by Portuguese, in 1881 by Norwegians and Germans, later by Russians and Spaniards, and finally, Filipinos. The changes in nationalities and the recruiting of families in place of single men have resulted in changes in housing. It seems better practice to build family houses rather than those designed for single men, as the family houses can be converted into dwellings for single men with minor changes. The H. S. P. A. convertible type of house has met with much favor. Although two-family houses for the smaller families are still in vogue, it is generally conceded now that the one-family type of house with separate sanitary facilities is the ideal.

## Sanitation Important

With the passing of the barracks type of dwelling, which housed large groups of both single and married men, the improvement of camps has been of steady progress. Solutions of housing and sanitary problems have been arrived at only after a careful study of the requirements and through the cooperation of all interested parties.

The greatest improvements made during recent years and the most noticeable are in camp sanitation. The community privy, indecent and unsanitary, is obsolescent; its place has been taken by sanitary facilities designed for the use of one family or small groups of single men. Improvements in facilities led to a study of the disposal of waste water and fecal matter. With the hearty cooperation of the different plantations, a lengthy study and a number of experiments were conducted. As a result, the H. S. P. A. method of sewerage disposal and sanitary outbuildings was developed. This method has been adopted as the standard by most plantations.

## Plan Your Camps

The general rule adopted before camp improvements are undertaken is to map out and place on paper the proposed new work, the map showing streets, lots, sewers, water supply, location of houses and sanitary outhouses, sewerage disposal, etc. These plans are then approved by the plantation manager and other interested parties. Building plans to suit the various requirements and local conditions are supplied by the H. S. P. A. These plans are carefully checked to insure their compliance with the various laws, rules, and regulations respecting housing and sanitation. Utility, comfort, and sanitation are the principal considerations.

The cost of housing and sanitation must receive careful consideration. The cost is based on the general type of construction and is usually figured at so much per square foot of floor space. Houses containing 480 square feet of floor space, including four rooms, two of which are bedrooms, have been found to fill

the general requirements. All sanitary facilities, with the exception of the kitchen sink, are placed in a separate sanitary outbuilding connected with the H. S. P. A. type of sewer.

While many splendid improvements have been accomplished, there is much to be done before all of our plantation villages can be classed as meeting present-day standards. The camp improvements completed during the past five years show a remarkable progress and prove the keen interest that is being manifested by the owners and employers of the plantations. Better types of houses, with adequate sanitary facilities and more healthful surroundings, are the rule.

We recognize that contentment with the housing and surroundings certainly has its effect on a man's producing power, and that good health influenced by sanitary and healthful surroundings plays an important part in keeping up the production by an increased turn-out and a decreased labor turn-over.

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# Cane Fires*

By J. S. B. Pratt, Jr.

Cane fires have such a destructive effect, with loss of investment, water, fertilizer, labor, and growing time, that the suggestion has been made that we discuss at our Sugar Technologists meeting ways of fighting and preventing fires.

Fires may be *accidental, incendiary,* or *intentional.* On a sugar cane plantation, we may have grass, trash, young cane, mature cane, building, and forest fires. In this paper, we will concern ourselves mainly with mature cane fires, but, in passing, it will be well to mention good ways to stop grass and trash fires.

## Grass and Trash Fires

The best aids in fighting grass fires are shovels of earth, trenches to prevent creeping, green branches, wet bags, and hoes. Grass fires give so much smoke that it is hard to work on the lee side. It is easier to work with the wind on two sides, pinching it to a narrow point. With large grass fires, time will be saved by using a plow and turning a few furrows. Trash fires are similar to grass fires, and in both, buckets of water thrown in a fine spray are very effective in checking the fire at critical points. When using bags, branches, or in throwing earth, be careful not to fan the flames. A large number of our cane fires are started from grass or trash fires, very often, because we get careless and burn without regard to wind or to dryness.

## Intentional Fires

In Hawaii, we have for a number of years burned off our cane before cutting. There is not only the labor saving in harvesting of very often as much as 40 per cent, but there is the labor saved in starting off the ratoons. J. A. Verret writes:

Burning off before cutting the cane was becoming the general practice about the years 1909 and 1910. Its general adoption was brought about mainly on account of labor shortage and lessened cost of harvesting. The first mention of burning before cutting made in the

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H. S. P. A. annual committee reports, as far as I have been able to find, was by W. W. Goodale in 1909. In 1910, L. Weinzheimer reported on this practice as then carried on at Pioneer Mill. Among the first places where burning was done was in the Lawai Section of McBryde in 1902. Kahuku, as far as I know, was the first place on Oahu. In the beginning, the practice was done not so much as a labor saver as on account of borers. I understand that burning off before cutting is a general practice in South Africa, where Uba is the standard cane. I know of no other country where burning off is practiced as a general thing.

Burning off destroys rats, diseased cane and injurious insects, and, of course, our friendly insects.

Experience is our best guide to burning off. One learns when to take the fire fast, when to go slowly, how to create a draft to make the sparks go up, when to have plenty of men at a fire, when not to burn, and so forth. At Pioneer, for instance, burning off early in the morning with only a few men at hand is customary. That is their job, to burn off, and to cut the firebreaks for the next day's burn. They become expert at it and use a very narrow firebreak with a small stream of water, taking advantage of an early morning breeze to make it safe. To one not used to burning off in this way, it seems dangerous. These men, however, are trained, are alert, and are active when a spark jumps. Men should be trained to be careful and not to be afraid. It pays to pick men for fires, and the more men are trained in this way, the more fortunate is the plantation when accidental fires occur. They gain confidence and are not afraid when trouble comes. Men of this type are worth sevenfold the untrained men, and with the untrained man, there is more danger of loss of life in our accidental fires.

### Accidental Fires and Incendiary Fires

These happen on the best organized plantations. Someone careless in smoking, a strong unexpected wind carrying a spark far from some burn, dry grass or trash, a locomotive spark, a nitrate bag left carelessly by cane, or even some firebug, disgruntled laborer, or strike agitator will start a cane fire.

Let us follow a cane fire through, telling what we would do and what we would *not* do. Experience is our best teacher for fighting fires, and some of us here may have certain experiences to tell our fellow members that may be helpful.

It is night, and Manuel, riding home from a visit to his old father, sees a glare in a nearby field. There can be no mistake in what it is. Fire! Some careless fisherman returning from the beach, drops a cigarette in the grass by the road that should have been cleaned, and the cane stripped back a line or two. But the fire has just started, and Manuel gallops on, knowing that the first thing he must do is to find if it is something he can put out quickly. Or possibly a few men in Camp 5 right nearby can put it out before it gets headway. At the start a few men can very often put a fire out, and if time is lost in going for more help the fire gains headway. Very often general alarms are given and, like the fable story of "wolf-wolf," men hold back after coming to a few false alarms. And a few men at the start taken quickly to the scene of the fire are better than arousing the whole plantation, losing time in so doing, and having poor turn-outs the next day.

But Manuel, on getting closer, finds that the fire is larger than it looked at first, and he must ride fast to give the alarm. He gets the night watchman at the

mill, or the nearest telephone to let the "higher ups" know. Someone in authority should be on the plantation at all times, for we have other people's money tied up in our fields and property.

The fire being a bad one, the general fire whistle at the mill is blown. I have seen many fires that did not require a lot of men. Small blazes are very deceptive at night. The general alarm should be given only when those in authority investigate and find it necessary. Minor fires may require only a truckful of men, but, of course, I would not hesitate if conditions warrant in arousing the whole plantation.

Steam is kept on one locomotive at all times that laborers may get to the fire, and that the alarm may be blown in case the mill is not running. The warehouse men rush to the warehouse to get the knives, hoes, shovels and buckets. The reservoir men and ditchmen already have standing instructions to get water in the nearest ditch, for in the excitement someone may forget this first requisite. These men know the ditches that carry the water in the shortest route, and they must be trained to think of water first.

Manuel, we leave with the other lunas in getting the men to the fire in trucks, autos, locomotive, on horseback, and on foot. The truck drivers know they must go to the camps to get the men who are already being aroused by the camp boss, and they must get their loads as quickly as possible, get to the fire, and then go back for more men. Their trucks are fully equipped with cane knives, as are all the locomotives, for a man must have some tool at a fire.

Fortunately, our fire has not gained much headway. The head overseer on reaching the fire sizes up the situation, where the firebreaks are to be, etc. Here the tendency is to get too close to the fire, making it impossible to do anything on account of the smoke, and making it more dangerous for the men. Also the backfire will then have no time to work back before the fire is upon it, and we have the whole thing to do over again. The fire jumps sometimes 300 feet, depending on the variety of cane, the wind, or the dryness of the field. May we digress here to the topic of *firebreaks*.

In choosing firebreaks, we must study the wind, its velocity and direction, the terrain, ditches, ridges, and roadways. A fire can be stopped on a ridge easier than in a hollow where the cane is heavier. It can be stopped in cane at the beginning of a season when the tops of the cane are green and there are no dry leaves to cause a jump. A small leaf like H 109 is better than a broad leaf like Yellow Caledonia. A recumbent cane is better than erect cane. A night fire is easier to watch for these flying leaves than a day fire. In studying the wind, one may find a way to almost change the wind around, by creating a draft from a backfire made in a certain direction. The flames may be made to go up as they would in a chimney. So it is important to pick the right firebreaks. Very often it may be best to start two firebreaks, working with the wind and pinching the fire. In this way, the men are in less danger and they are in fresh air, so that they can be called when the critical time comes, and not be exhausted. And repeating, do not cut the firebreak too close to the fire. Take plenty of room.

Having chosen our firebreak, the first essential is that the men know what to do. Here is where the lunas come in. One often sees a luna trying to put the whole fire out himself, having twenty of his men standing by, topping cane here and there, and not being directed. Men must be stationed to direct the others

coming to the fire. Pick out the old men, the ones that are not so useful in the fire, to stay by the main road, the ditches, etc., to show the stragglers where they are to go, or where they are to get knives. These precautions avoid confusion. Much needless expenditure of energy occurs where there is no directing head in charge, or where different plans are being followed. Someone starts a backfire and then the work must be done all over again.

Backfires are very necessary at times, but they may be dangerous and men may be trapped. And backfires often jump. Gangs working on both sides of the fire, out of the smoke, and pinching the fire to some ridge or corner of the field, can very often stop a fire without the danger of using backfires. The first essential in fighting a fire is to think of *life,* and one should not send men into a fire where one would not go himself, or where there is too much of a chance.

To go back to our fire. Our men know where to go and what to do. Our control means are firebreaks, backfires judiciously used, water, roads, ditches, green cane tops, shovels of earth, wet bags, and fire extinguishers. Green cane tops we place on the flames, keeping the flames down so that we may work the fire to a smaller head. In this connection, there is nothing more effective than buckets of water, and here training helps. A man who has never thrown a bucket of water, throws it in one place. Properly, it should be thrown in a fine spray in a motion similarly used by fishermen in throwing a throw-net. The finer the spray, the more effective it seems, for the water covers a wider area, and those of us who have burned off know that a small sprinkle of rain will often put a fire out that had been going very well. This year, I have carried a half-dozen buckets in the back of my car, and on several occasions they have materially stopped cane fires. I also have cane knives there. And each harvesting field is equipped with a box containing chains, links, double-trees for the hauling, and cane knives, buckets and shovels for emergency use.

One never knows how a man will act in a fire. Some are nervous and make others nervous. I would rather have a gang of a few trained confident men on a fire than too many men that do not know what to do and get in each others' way. Cane cutters who burn daily are the best at fires, but they will hang back unless proper leadership is shown. Even the directing head should occasionally jump in and spur the men on. But the leaders should prevent the men from crowding and thereby prevent accidents.

By hard work, then, our fire is out. We must be careful, right up to the end, for many a fire jumps at the last stretch when the fires from the two sides rush together. Or possibly we thought we had it out and had gotten too confident and had allowed a tiny flame to creep in some trash in the firebreak. We must leave men back to see that no spark fans up or stump smoulders. At night, when the flames are out, we are glad that we had our flashlights with us, so that we can see that all the men get out. The timekeepers then see that the men have time allowed for their work at the fires, and we go home exhausted, but with more experience on cane fires, particularly in learing what *not* to do.

### Deterioration

Having had our cane fire, the questions always come up as to what we are going to lose; should we leave the cane standing or cut it all down as fast as we can; and after how many days will it be fit for the mill, etc.?

There are two reasons why I like to cut the cane down fast. One is that the men are keyed up to the fact that the plantation has had a fire and they will work harder. Next is that unless there is plenty of cane cut ahead, the track men cannot work, the loaders cannot load, the hauling is tied up and we do not get the cane into the mill at the greatest possible speed. Perhaps in wet weather it is better not to cut too far ahead for we must remember that we have two ends on a cut stalk for fermentation to work, though inversion starts quickly from the top of the stalk anyway.

Quoting from J. A. Verret, who has collected deterioration figures from all the Islands:

> In regard to burning, the best figures we have are from the Ewa tests, on mature cane, in hot, dry weather, which figures are closely corroborated by many others on all the Islands.
>
> The losses averaged about 3 per cent a day, or, say 15 per cent in five days. The loss on the first day is not so high. One thing to remember in this connection is that this loss consists not only in the deterioration of the juice but also in loss of weight in cane. As your cane gets older, you are having losses even when your juices show no change. Our tests show that there is no advantage to allow burned cane to stand rather than to cut it.

With regular burning daily, we should have no old cane. At McBryde, we make small burns, and figures kept on a year's harvesting show that 14 per cent of the cane reaches the mill within 12 hours from burning, 39 per cent is 24 hours old, 36 per cent is 48 hours old, and 10.5 per cent is 72 hours old, or a total of 99.5 per cent reaches the mill within 72 hours. The remainder, or one-half of one per cent, comes in within 96 hours and is cane sometimes held over Sunday, or because labor turn-outs were poor, or because the burn was misjudged as to tonnage.

### Precautions or Prevention

1. Our men should know what to do and where to go.

2. They should be trained in fire fighting, and there is no better way than to instruct them daily when burning off, that they may thereby gain confidence.

3. The field layouts should be studied and corrected, that we have no large fields of cane of the same age adjoining. We thereby lessen our fire hazard and possibly distribute our water better. Incidentally, we intensify our culture.

4. Have plenty of field roads and ditches. They should be laid out as firebreak aids. Water is the main requisite for most plantations. The land given up to roadways is not lost, for we have better aids to supervision and to the cutting of firelines in regular harvesting and emergency, especially where we have heavy cane and firebreak cutting is slow.

5. Have all roadways stripped of trash, grass or fire hazards.

6. Have a general understanding for truck drivers, ditchmen, lunas, etc., as to what they are to do.

7. Have tools handy, especially knives and buckets.

8. Fire extinguishers. Several places have a battery of fire extinguishers for fire fighting. Their value comes in keeping the flames down in critical places. They must be tested and kept filled regularly, for often some laborer turns one over and then, of course, it is of no further use. Take one out to a regular burn-off and show the lunas how it is to be used. The locomotives should carry them;

so should the trucks. Hawi Plantation has a truck especially equipped with knives, extinguishers, chemical tank, buckets, and other fire apparatus.

9. The overhead system of irrigation lends itself to easy burning and to control of fires.

10. One good rule to try to follow is to burn off early in the morning, before the sun has a chance to dry the light dew off the leaves. The leaves will then be less apt to carry jump fires. Some plantations get night showers, making morning fires difficult, but it is well to remember that a day fire must be watched. The winds vary more in the day, when the sun is up, and we may then not have our regular night mountain or sea breeze.

11. In daily burning off, caution the men to be quiet, so that if the fire jumps, a warning can be heard. Keep the men out of the smoke as much as possible, so that they are fresh in an emergency.

12. Beware of trash and grass fires, for many a gust of wind or creeping has started a cane fire.

13. Have the locomotive stacks inspected regularly; even oil burners start cane fires, possibly from some leaky pipe.

14. Cut the firebreaks to run as much as possible in the same direction as the wind.

## Summary

We may control cane fires much more effectively if our men are trained, if they know what to do, and have confidence. They must have means for fighting fire, such as water, tools and transportation. There must be a directing head, otherwise there is much needless energy expended. The better we are organized for fire emergencies, the more chance we have of preventing loss and lessening accidents.

## Questions For Discussion

1. Has anyone an organized system for fighting and preventing fires?

2. Has anyone interesting experience to relate on a fire?

3. What is the worst cane fire remembered? How many acres, tonnage, cause, days before finished, etc.?

4. Has anyone found a fire extinguisher of value in a cane fire?

5. Has anyone figures on the average number of men required daily in cutting firebreaks? How are they cut, by allotment or by regular firebreak men? Is trash piled on windward or lee side. How about cane?

6. After a bad fire, how long has the cane been in good weather before the last stick was ground?

7. Am I right that a backfire should never be started until necessary?

# The Factory Problem of Clarification*

By Walter E. Smith

Clarification of cane juice is seen on analysis to consist of four main physical or chemical reactions:

1. Flocculation of colloids by change of hydrogen ion concentration.
2. Flocculation of those colloids which are coagulated by heat.
3. Formation of insoluble lime salts.
4. Formation of soluble lime salts and chemical reaction products.

The production of a clear resulting juice is apparently the combined result of flocculation by change of reaction and heat, and the formation of insoluble lime salts. Simple change of reaction, together with heating, will not of itself result in the clear, sparkling clarified juice which is met in practice, because apparently certain colloids are not precipitated under these conditions; much of the suspended matter remaining in colloidal dispersion is carried down, however, by occlusion within the flocculent and voluminous precipitate of calcium phosphate produced by the reaction of the lime with the phosphoric acid of the cane juice. Thus the two phases of the reaction supplement one another and combine to produce juice of varying clarity, depending apparently on the over-all efficiency of the two factors in the reaction—the efficiency with which the colloids are coagulated by heat and alkalinity alone, and the production of the calcium phosphate precipitate. This theory of clarification offers a fitting explanation of our practical observations: that for a given phosphoric acid content, the clarity of the juice reaches its maximum slightly beyond the neutral point of phenolphthalein in the cold limed juice, thus establishing that as the optimum point when clarity of juice is used as the basis for comparison; that for a given reaction the clarity of the juice increases with increase in phosphoric acid, although not necessarily in this proportion after we reach an amount sufficient to meet the requirements; and last, that juice deficient in phosphoric acid will not yield bright, clear juice even if the reaction is at the maximum permitted by other working considerations.

The formation of soluble lime salts and chemical reaction products may be considered as an incidental phase of the question, introducing other factors which may set a limit on the extent to which we may carry liming; of this more will be said later.

For purposes of continuous operation, general practice favors heating juice practically to the boiling point or slightly beyond; this seems to give best flocculation and reduces the volume of settlings to the minimum for the existing conditions. With this factor set approximately at the boiling point, the only remaining factor within our control is that of the reaction at which clarification is conducted.

The ideal reaction is that which would give us:

1. Maximum elimination of non-sugars.
2. Minimum liability to loss by inversion.
3. Most complete flocculation of colloids, and most rapid settling.
4. Greatest clarity of resulting juice.

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

Of these, the first two are of paramount importance, affecting as they do the final recovery; the third, while actually a limiting factor in many cases, should really be subordinated to the main issues and may ordinarily be adjusted by the installation of sufficient *suitable* equipment properly operated. Clarity of juice is desirable as this becomes one of the major factors in determining the filtering qualities of the sugar produced.

Clarification investigations conducted at the Experiment Station have shown that in general the maximum increase in purity between mixed juice and clarified juice is obtained at a reaction of 8.0-8.3 pH in the hot limed juice Further examination of this reaction from the standpoint of the ideal set out above shows it to meet fully the second and fourth requirements.

At an original reaction of 8.0-8.3 pH, the clarified juice will not fall below 7.5 pH and at this, hydrogen ion concentration inversion will proceed so slowly, even in juices heated to the boiling point, that under practical working conditions losses may well be considered negligible. Further, at this reaction the clarity of the resulting juice reaches a practical maximum.

The advantages which accrue when clarification is carried at a reaction of 8.0-8.3 pH in the heated juice are so specific, under Hawaiian conditions, as to warrant proceeding on the basis that this shall be the ideal at which we aim, and any attendant disadvantages must be considered simply as difficulties to be overcome. *To maintain clarification at this optimum reaction, meanwhile operating at normal grinding rate and at full efficiency from the conventional standards of boiling house practice, may then be considered "the factory problem of clarification."*

## Liming

The problem of actually maintaining the desired reaction uniformly and regularly is one of fundamental importance; by this is meant liming *all* the juice to the same hydrogen ion concentration, so that every portion of juice leaving the receiving tank below the scales is at the desired reaction. It is not sufficient to maintain the reaction of the clarified juice at a point corresponding to the desired hydrogen ion concentration for the heated juice; great variations between parts of individual scale tanks might exist at the time of heating, but a satisfactory average could still obtain after mixing in the settling tanks. With an average reaction of clarified juice corresponding to 8.0-8.3 pH in the heated juice, if irregularities exist in the original liming it must mean that some of the juice was considerably alkaline to phenolphthalein. In this portion of the juice it is certain that there would be abnormal destruction of glucose, and the cush-cush present would likewise be subjected to more than normally vigorous digestion with attendant disadvantages through solution of non-sugars. Whether or not other reactions taking place are reversible we are not in a position to say, though the two mentioned undoubtedly are not; however, observations by W. L. McCleery during factory inspections show a distinct improvement in the relation between turbidity, as measured by the Kopke turbidimeter, and phosphoric acid in the juice, when the liming was made uniform. The exact effect of irregular liming is perhaps difficult to demonstrate, but one of the most important reasons for absolute uniformity of liming is that without it we have no efficient basis for control. To base control of liming on the reaction of the clarified juice is funda-

mentally wrong, since it does not follow that any relation exists between the lime requirements of any particular quantity of juice entering process and of juice which preceded it by two hours; acidity of juice being discharged from the settling tanks obviously cannot be corrected by increasing the reaction of the juice then entering the heaters.

The most serious irregularities of liming appear to exist where there is only one receiving tank below the scale, in which the lime mixing is done while juice is being constantly pumped out, and to which quite over-limed press juice is being returned. As this receiving tank empties, just prior to the discharge of a new scale of juice, the alkalinity of the limed juice may be very high due to the large percentage of press juice. As the scale is discharged the lime measuring tank is emptied simultaneously and usually the entire amount of lime has been added while probably less than 10 per cent of the juice has been discharged from the scale. Thus the first portion of juice pumped to the heaters is distinctly over-limed, gradually decreasing in alkalinity until the scale is completely emptied, when the alkalinity again begins to increase toward the peak reaction. With the constant change in alkalinity of the limed juice it is seen that at only one brief period is the reaction equal to the average, and as a result it is practically impossible to estimate the actual lime requirements by tests of the cold limed or heated juice proper. The only indication is the reaction of the clarified juice at the time of drawing off, and this, of course, is quite inadequate for purposes of control.

This condition, however, can be easily remedied without recourse to the installation of extra tanks or changed liming systems. By a little experimentation the opening in the bottom of the lime measuring tank can be so regulated that practically the same length of time is required for emptying as for the discharge of the scale; if the lime is mixed with the juice immediately below the scale discharge valve, a rather thorough mixing will result, though it is well to supplement this mixing with agitation by compressed air. With such an arrangement the writer has succeeded in regulating liming so that the uniformity of reaction left little to be desired. Where press juice is returned to the mixed juice this is very satisfactorily handled by installing a receiver of small diameter (10-12″) and extending in height to the upper level of the receiving tank in the line to the raw juice pump. If the press juice is pumped to this receiver it will mix with the limed juice at a uniform rate and will be equally distributed, thus avoiding irregularities of reaction.

An arrangement having two mixing tanks with one scale, or three mixing tanks for two scales, gives a more flexible and more positive arrangement for the control of liming. Here the lime is added to a fixed quantity of juice, mixing is completed and the reaction tested before the juice is pumped to the heaters. Once the alkalinity is adjusted the entire contents of the tank may be depended on to be the same; press juice may be disposed of in the same way as previously described.

One further system is the use of continuous liming devices such as the Fleener arrangement, or that used in connection with the Petree-Dorr process. Theoretically, continuous liming should make possible an absolute uniformity of reaction, combined with a very positive control; the writer is inclined to believe,

however, that more serious irregularity is likely to be encountered with continuous devices than with a proper intermittent arrangement. With intelligent supervision the continuous installations work entirely satisfactorily, but in the smaller factories, where operation is likely to depend on unskilled laborers for considerable periods, intermittent liming seems less likely to result in operating difficuties occasioned by serious over- or under-liming.

No real reasons exist, however, for the marked irregularities in the reaction of individual parts of the same tankful of juice as found in many factories and by only minor changes the system can be adjusted to give satisfactory uniformity of liming. This is the very crux of the entire situation—the ability to maintain the reaction at just the right point with certainty—and no effort should be spared to achieve this end.

### Heating

Juice heating presents no problem of special difficulty; with sufficient heating surface and a suitable steam pressure, the juice temperature should be readily controlled. Difficulties may usually be traced to one of four sources: Improper discharge of condensate, incomplete venting of non-condensible gases, improper cleaning, or throttling between the exhaust mains and the steamer chest of the heater. The proper functioning of traps is a mechanical detail that may be readily adjusted. Equal care should be given to the proper venting of incondensible gases, especially where heating is done with vapor from a pre-evaporator; where vapor heating is practiced provision should be made to prevent air being drawn into the steam chamber of the heaters in the event that the vapor pressure falls below atmosphere; this is readily accomplished by the use of check valves on the vent lines. At one factory the work of the heaters was greatly improved by venting the incondensible gases under vacuum. In this case the vents were connected to the third effect, rendering the work of the heaters automatic and regular, the temperature of the juice varying with the pressure of the steam applied at the calandrias of the pre-evaporator cells.

If the juice is heated to or beyond the boiling point it should be given opportunity to flash before entering the settling tanks; this seems to break up the foam and scum which otherwise would float on the surface of the juice in the settlers. A number of factories are equipped with a so-called pre-settler which acts as a combination flash tank and supply tank. Probably one of its principal functions is to act as a scum separator; on flashing into this pre-settler, such foam as is produced will rise to the top, and since the juice is drawn off from the bottom no floating scum will be carried over. When this scum breaks up and sinks of its own accord, it is in a state in which it will likewise sink in the settling tanks. Without such an arrangement considerable difficulty with foam is likely to be encountered.

### Settling and Decantation

Maintaining clarification at the optimum reaction of 8.0-8.3 pH brings with it the specific problem of an increased volume of settlings. Laboratory tests and actual observations under operating conditions have well demonstrated that the volume of settlings increases progressively with the hydrogen ion concentration of the juice, reaching its maximum in most cases at a point somewhat alkaline

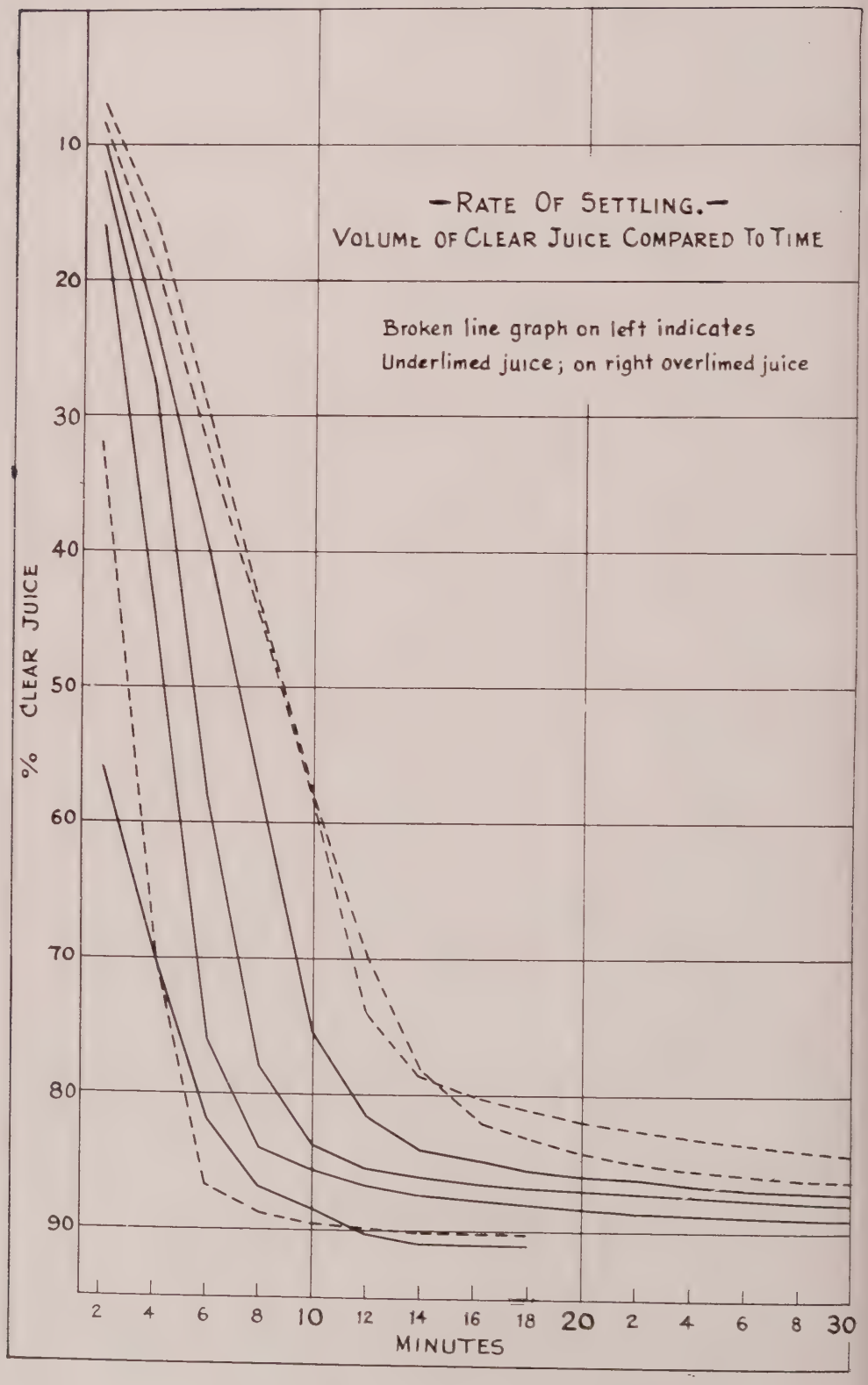
to phenolphthalein. This becomes a limiting factor of the reaction at which clarification may be conducted if there is not available sufficient capacity at the filters to compensate for the increased duty imposed on that station.

Many operators interpret the conditions which exist when clarification is maintained at the optimum reaction as "slow settling." On this point the writer agrees with the opinion expressed by W. R. McAllep that the condition is not actually one of slow settling, but simply one of increased volume of settlings, the precipitate coming to rest and settling to its ultimate volume in approximately the same time required for settling at a less alkaline reaction. Mr. McAllep has prepared the accompanying graph from data furnished by Noel Deerr in his publication, *Cane Sugar,* which fully demonstrates this point. These curves indicate that during the first part of the settling cycle the precipitate follows the physical law pertaining to the fall of bodies through a resistant medium; during this period the graph is practically a straight line until it reaches a so-called "critical point," after which the shrinking or contraction of the volume of settlings becomes quite small and of little practical significance. This data, confirmed by actual observation of the conditions in question under operating conditions, indicates quite clearly that *the solution of the question of increased volume of settlings must be approached on the basis of actual disposal by filtration rather than attempting to reduce this volume by extended settling to equal that obtained with less alkaline clarification.*

Once the precipitate settles to the critical point no material reduction in volume will follow; certainly this reduction will not be proportionate to the extension of time. If sufficient capacity exists to permit holding the juice an hour and a half this should be sufficient to bring the volume of settlings to a practical working minimum; indeed, considerations based on the development of acidity and inversion at the high temperatures normally existing in the settling tanks would indicate that the cycle should not be lengthened much beyond this limit. It would seem more economical, and certainly more consistent with the principles of efficient operation, to provide the remedy by increasing the capacity of the filter station.

A factor of considerable importance as affecting the settling cycle is the disposal of filter press juice. When working with cane juices high in phosphoric acid, at the optimum reaction the volume of filter press juice is likely to amount to fully 20 per cent of the mixed juice. Obviously, if this is taken back to the raw juice for re-settling the duty imposed on the equipment is increased 20-25 per cent, thus reducing the settling cycle by that amount. The practice of returning the filter press juice to the raw juice is defended principally on the ground that this is a safeguard against contaminating the clarified juice through broken filter clothes. This, however, only temporizes with the problem; the real solution must be to so organize the work of the filter press station that it can be depended on to deliver clean juice at all times without danger of allowing dirty juice to re-enter the system. Probably half of the factories now do so in an entirely satisfactory manner, which is ample proof that the scheme is entirely feasible.

The principal objection which may be aimed at the intermittent settling tank is the fact that a considerable portion of the total juice must be decanted from a zone immediately over the mud line. This disadvantage makes itself evident in


—Rate Of Settling.—
Volume of Clear Juice Compared To Time
Broken line graph on left indicates
Underlimed juice; on right overlimed juice
% Clear Juice
10
20
30
40
50
60
70
80
90
2 4 6 8 10 12 14 16 18 20 2 4 6 8 30
Minutes

many ways. Frequently the juice discharged from the lower draw-off is not so clear as that from the upper valves, due to the fact that the currents set up immediately over the mud line carry over just sufficient mud particles to make the juice turbid, but not sufficient to warrant turning this juice to the mud trough. This disturbance becomes more exaggerated if the rate of draw-off is increased, and to prevent this the tendency is to draw off more slowly from the lower valve than is actually necessary, resulting in a reduction in the efficiency of utilization of settling capacity. In some cases, the writer has seen a third of the total settling tanks in a factory practically out of service because of the slow rate of draw-off from the lower outlets.

Conversely, the principal advantage of the continuous type of settling tank lies in the fact that the juice is drawn off at the maximum distance from the mud line. Despite this fact, however, several installations of continuous settling tanks fail absolutely to deliver juice of equal clarity to that which might be expected from similar clarification procedure with intermittent tanks. In one particular installation with which the writer experimented, both intermittent and continuous settlers were supplied with heated lime juice from a common supply tank; the intermittent tanks never failed to give juice of superior clarity.

With intermittent settling tanks of conventional design, when clarification is carried at even moderate alkalinity, the level of the mud will in almost every case lie between the lower and middle outlets. Many factories follow the practice of drawing off mud through the lower draw-off until clear juice is discharged from this valve, at which time the juice is diverted to the clear juice trough.

The result of this rapid draw-off must certainly be to set up currents within the tank which result in drawing off with the mud a considerable volume of clear juice as well. Much better results should follow if the heavy mud is drawn out through the mud discharge valve, thus lowering the level of the mud line below the lower outlet valve; in this way, since the movement of the juice and mud is in a downward direction, no disturbance should result. If mud to be filtered is drawn only from the bottom valve, the mud or dirty juice trough may be connected to the limed juice receiving tank; the only juice then turned to this trough would be that first drawn off from each valve, and the juice from the lower outlet in the event that it ran dirty through too rapid discharge. By diverting this juice to the mixed juice for re-settling the duty on the filters may be considerably lightened and the ratio of solids to liquid in the settlings may be maintained at a higher figure.

### Filter Press Operation

The problem of maintaining clarification at the optimum reaction is in large part a matter of capacity for the filtration of settlings. While it is perfectly obvious that the filter press station should be operated to fullest efficiency, the fact remains that little agreement exists as to the ideal conditions for filter press operation. Filtration as a chemical engineering problem has received considerable attention, but specific data pertaining to the filtration of cane settlings is entirely inadequate to enable us to definitely lay down a series of rules for the conduct of this operation. Assuming that filter press equipment is in good mechanical order, that the frame surfaces are clean and permit proper tightening, that the cocks

are in good tight condition and that the inlet and outlet ports in the frames are free from obstruction, there remain two principal factors on which no agreement seems to exist: First, pressure of filling; second, reaction of the settlings.

The matter of pressure is found to vary among our best factories from as low as 10 lbs. per square inch to as high as 40 lbs. The writer cannot conceive of such radical differences in the filtering characteristics of settlings as to make these extremes justifiable; surely both cannot be equally efficient, and yet the fact remains that data is not at hand to definitely demonstrate the efficiency or correctness of either pressure.

While formulas for filtration developed in chemical engineering practice may not be specifically applied to the solution of our problems, they at least indicate the factors involved, and from them we may arrive at an understanding of the most beneficial operating conditions. Filtration may be considered as a flow through a capillary tube, for which the equation shows flow to be proportionate to the pressure and to the fourth power of the radius of the tube, other conditions being equal. With a gelatinous, highly compressible material such as cane mud, it seems quite obvious that the porosity of the cake will be affected by increased pressure; since decreasing the radius of the interstices of the cake one-half will reduce the rate of flow to one-sixteenth, the importance of the appropriate pressure becomes apparent.

When handling solids of crystalline or granular texture, increase of pressure results in almost proportionate increase of filtrate, but with a flocculent precipitate the head may often only be increased a few feet before a contrary result is obtained. Wright, in his text, "Industrial Filtration," says: "The reason that, in practice, the law of increased pressure does not always increase the flow, is found in the fact that in filtration the orifice (i. e., cake porosity) becomes a variable under pressure. For every material there is a pressure above which an increased flow is not obtained, but a decreased flow is had instead. This is known in filtration parlance as the *critical pressure* for that material."

These theoretical considerations are well borne out by observations made under actual working conditions. One factory noted for the excellence of its filter press work as measured by the low polarization of the press cake, employs a gravity head equal to a pressure of 10 lbs. per square inch.

Obviously filter press work must be considered as a combination process of filtration and washing, and filtration proper must proceed in such a way as to leave the resulting cake permeable to water so that excessive time is not required for washing; unless this condition is met, any saving by the use of high pressure is lost through the extended time required for sweetening off the mud. At the factory in question, timing of the filtration cycle over a period of three days gave an average of two and a half hours for filling, and a few minutes over two hours for washing, resulting in a press cake of approximately 1.0 per cent polarization. These results compare favorably with any being secured at other factories and demonstrate the effectiveness of low pressure filling. Ease of washing press cake to a low polarization in a short period may be accepted as an indication of cake porosity, which, in turn, is a measure of the interstices between the solid particles making up the cake; this should indicate a high rate of flow, a condition actually demonstrated by the short filling time quoted.

During the past season the writer had opportunity to experiment with filtration of settlings at two factories, one where the settlings came from juices low in phosphoric acid and were comparatively low in volume, the other from juices moderately high in phosphoric acid and the volume of settlings so high as to constitute a serious problem in clarification.

In the first case, under customary operation, the pressure was allowed to build up to 40 lbs., at the end of the cycle, the filtering cycle varying from three to seven hours; the polarization of the press cake averages approximately 2.5 per cent; nine presses were used and frequently were of insufficient capacity. A centrifugal pump was installed and operated to give 18 lbs. pressure at the presses; the number of presses in service was reduced to the minimum, each press being forced to the limit at the pressure available. Under these conditions, it was found possible to fill the press in somewhat less than three hours, but to reduce the procedure to routine the filling cycle was arbitrarily set at three hours; washing was likewise set at three hours per press. The net effect was to reduce the polarization of the cake to approximately 1.5 per cent, at the same time increasing the capacity of the station to such an extent that usually at least three presses stood empty. The quality of the press work was such that the juice was taken direct to the evaporators and at no time was difficulty experienced with broken cloths or dirty juice.

In the second case, filtration had been conducted at a pressure of 35-40 lbs., with washing following at 50-60 lbs. At this pressure the leakage during washing was so great that the full maceration requirements of the mill were met by the quantity of sweet water produced, amounting to 1,600 per cent on the weight of cake. When the presses were filled by centrifugal pump at 15-20 lbs. pressure, no difficulty was experienced in maintaining a rate of flow equal to that obtained at 40 lbs. The leakage was materially lessened when the washing pressure was reduced to 30 lbs., and the polarization of the cake dropped to about half of that secured on preceding days. Likewise, juice leakage during filling and the danger of broken bags was so reduced as to make it possible to divert the filter press juice direct to the evaporators, a practice previously considered unsafe.

In general, practical data available indicates that the critical pressure for cane settlings is more likely to lie below 20 or 25 lbs. than above, and high pressure does not seem advisable, particularly since this increases the danger of broken bags and thus makes unsafe the practice of returning press juice direct to the evaporators.

Filtration practice, in beet sugar manufacture as well as in other chemical engineering industries, is almost unanimous in favoring the use of centrifugal pumps for press filling, though for pressures up to 15 lbs. most cane factories could conveniently arrange a gravity feed. This is equally satisfactory, but in many cases would perhaps prove as expensive as the installation of a centrifugal pump.

One further factor of considerable importance is the reaction at which filtration is conducted. In many factories the settlings are carried distinctly alkaline to phenolphthalein, while in others no further lime is added to the settlings after the original liming of the mixed juice. Perhaps a slight increase in rate of flow is secured by adding sufficient lime to bring the juice to approximately 8.0-8.5

pH, but other considerations would indicate that this reaction should not be exceeded; at this alkalinity the press juice may be safely mixed with the clarified juice without bringing about a new precipitate, if the original liming has been carried to a reasonable degree. It is interesting to note that experiments conducted locally with a type of filter not previously used on cane mud indicated no increase in rate of flow through heavy liming.

### Fine Juice Straining

Extensive laboratory investigations at the Experiment Station showed that during the course of clarification the action of lime and heat on the particles of cush-cush present in the mixed juice brought about the solution of certain non-cellulose constituents, resulting in a decrease in purity. The development of the Peck juice strainer, using screen of 100-150 mesh, has been a practical effort to avoid this decrease in purity by removing the major portion of the fine cush-cush usually present. Mechanically, this juice strainer has been successful in removing approximately 50-60 per cent of the suspended matter from the mixed juice but resulting difficulties in filtration of settlings have been so marked, in some cases, as to offset the expected advantages.

Reviewing the situation at this late date, it is evident that the difficulties actually encountered were only to be expected. Filter equipment in use in the various factories was originally installed on the basis of the conventional standards, which, in turn, were developed from actual operating tests with material having the filtration characteristics of settlings containing the usual amount of solids. Removal of these solid particles would obviously change the filtration characteristics in an adverse direction and capacity which previously had been ample would immediately prove insufficient. As a remedy for the increased difficulty of filtration, rather than increase filtering area, an effort was made to change filtering characteristics back to the orginal condition by heavy liming, but this was only partially successful. In any event, the writer believes that this is the wrong direction in which to proceed, because by increasing the alkalinity of the settlings prior to filtration, in all probability the net result is to offset the original advantages obtained by the removal of the cush-cush. Approximately half of the original fiber still remains in the juice after fine straining, and this is in turn concentrated to the settlings; if, however, these settlings are now maintained at a distinct alkalinity to phenolphthalein half the original cush-cush is subjected to many times the severity of chemical treatment which the process is designed to avoid. It is not improbable that as much material is dissolved from the cush-cush in the settlings under the new conditions as from the full amount of fiber present without fine-screening at the lower alkalinity of settlings carried under normal conditions.

The writer believes that the scheme in operation at Pioneer Mill represents the ultimate solution of the fine straining problem under current conditions, when working with plate and frame presses of the present type. Here the material screened from the juice is returned to the settlings; consequently, there is no change in the filtering characteristics of the scums; filtration proceeds without addition of extra lime, and the net gain secured by the removal of half the cush-

cush during the heating and settling cycle (the period of highest temperature and highest reaction) is actually retained.

### Lime Salts

Experimental data shows that after the reaction of the juice passes the optimum point, there is a material increase in lime salts. The difficulty in boiling juices resulting from alkaline clarification, which some operators consider an objection to so-called "higher liming," does not seem to be actually corroborated by facts, since a great many factories proceed at the optimum reaction without noting difficulty in boiling. The question probably resolves itself into proper cleaning of heating surfaces, and if this is done efficiently, satisfactory boiling should be obtained. The use of a small amount of soda ash in the juice is recognized as a material aid in keeping the heating surfaces clean and the expense can probably be offset by a corresponding reduction in the amount of caustic soda necessary for boiling out of evaporators and pans.

## Clarification in Factories Operating Only on Single Shift

In factories which operate twelve hours per day, necessitating the hold-over of juices for twelve hours, clarification procedure becomes a problem of special importance, for here, unless proper precautions are taken, losses through inversion during the hold-over period may reach serious proportions.

Sucrose loss during hold-over may take place for two reasons: First, due to the development of acidity through heat, which may cause the juice to reach a reaction at which the rate of inversion becomes sufficiently rapid to cause material loss of sucrose; or second, through bacterial activity when the temperature reaches a level at which this may take place.

Data made available through clarification studies conducted at the Experiment Station show a striking difference in the rate of acidity development at various temperatures; at 210° F., the development of acidity proceeds at approximately four times the rate found at 180° F. For juices to be held over night, the obvious procedure is to reduce the temperature to the limit imposed by other operating considerations. Complete coagulation of proteids is best secured by heating to a minimum at 180° F.; on the other hand, 165° F., has been set as the safe lower limit to prevent the activity of bacteria and organisms which are found in cane juices. Thus the primary requirements for temperature control are that the original temperature should not be less than 180°, and sufficiently high so that the final temperature will not fall below 165°. With juice to be held over the week-end for a period of thirty-six hours, if the temperature loss by radiation is three-quarters of a degree per hour, the initial temperature must not be less than 192° F., and with a suitable factor of safety the heating would ordinarily be carried at 200° F. At this temperature, however, the development of acidity would proceed at such a rate the juice limed to the optimum reaction of 8.0-8.3 would no doubt have a final reaction low enough to cause appreciable loss through inversion. If, on the other hand, the insulation of the settling tanks was such as to reduce the temperature loss to one-third of a degree per hour, an initial temperature of 185° would be sufficient to assure a final temperature above the bacterial danger point.

and at this temperature the final reaction would be such as to exclude the liability of appreciable inversion.

These conditions are well illustrated by actual data obtained at the factory of Hawaiian Agricultural Company during the past season. At this factory the tanks are insulated on the sides with the customary 1½″ magnesia blocks, and in addition the bottom cone is now covered with a 2″ layer of asbestos cement, with the top completely sealed in with a similar covering.

Previous to following a systematic plan of reducing the temperature, the juice to be held over was treated with *double* the quantity of lime required during regular operation to bring the juice to slight alkalinity to phenolphthalein in the cold juice, and in addition a considerable quantity of formalin was added. At the end of 36 hours this juice had a temperature of 190-195° F., but the reaction was reduced to 5.4-5.8 pH; at this hydrogen ion concentration the loss through inversion undoubtedly became serious.

When the temperature of juices held over was reduced, the reaction of the heated juice at the time of filling the settling tanks was carried at only 8.0 pH, no variation being made from the liming as practiced during the regular day's operation, and in addition the use of formalin was discontinued. The following typical data will demonstrate the effect:

| | Temperatures in ° F. | | | Hydrogen ion Concentration | |
|---|---|---|---|---|---|
| Tank | Initial | Final | Drop | Initial | Final |
| 4 | 182 | 165 | 17 | 8.0 | 7.3 |
| 5 | 184 | 166 | 18 | 8.0 | 7.3 |
| 6 | 183 | 167 | 16 | 8.0 | 7.3 |
| 7 | 182 | 166 | 16 | 8.0 | 7.4 |
| 8 | 186 | 168 | 18 | 8.0 | 7.2 |

Total time of hold-over—38 hours.

At this final reaction, experimental data indicates that the possibility of loss by inversion is negligible as a practical operating factor. In over-night hold-overs, the same principles apply. At the factory in question, no change in liming was made in the juices; this has the special advantage that the conditions for ideal clarification are maintained even for the juices to be held over. Under the previous system, these juices, amounting to perhaps 15 per cent of the total production, were seriously overlimed, with the attendant darkening in color and destruction of glucose, *without eliminating the losses by inversion.* Daily measurements of initial and final temperatures, together with pH values, showed that the temperature loss could be reduced to approximately 0.4° or less per hour, and that by liming only to slight pink to phenolphthalein in the cold juice the final reaction would be approximately 7.4-7.6 pH; this may be considered entirely satisfactory.

Special precautions should be taken to avoid holding over any quantity of juice in partly filled tanks, since under these conditions the temperature loss is much more rapid than in full tanks. Some factories follow the practice of leaving the settlings in the tanks on the last two or three settlers emptied before closing down; while this is, of course, much better than dropping the settlings to uninsulated tanks, an even better scheme is to make suitable piping connections so that these settlings may all be pumped back into one settling tank and there held during the shut-down period.

For factories operating one shift, the writer believes that to equip each settling tank with an individual thermometer is one of the best investments that could be made; this gives the operator a chance to know definitely what is being done, a basis for judging the effectiveness of the insulation, and a control on the accuracy with which the over-all plan is being followed. A satisfactory thermometer may be purchased for $3.00. Measurement of pH values on each individual tank of juice held over will in many cases throw a good deal of light on the source of undetermined losses and will effectively demonstrate the necessity of exact temperature and reaction control. The development of color charts for the measurement of hydrogen ion concentration now makes possible an accuracy of control that heretofore has not been possible, and the factory operator who fails to take advantage of this opportunity to put the control of juice preservation conditions on a scientific and reliable basis is not availing himself of what is without doubt the most important development in sugar factory control made within a considerable period. Without considering unimportant theoretical objections which might be made against the color charts, the fact remains that their use makes possible a definite measurement of conditions of acidity and alkalinity which may in turn be compared to definite standards of procedure. As a result of a great deal of experimental work it can be said with certainty that if the reaction of the juice is maintained at or above 7.5 pH, inversion as a practical factor will not exist. This leaves little to be desired from the standpoint of developing a working program for the operation of a sugar factory; it simply resolves itself to maintaining proper initial conditions of temperature and reaction to the end that the final hydrogen ion concentration will lie above the danger point. The color charts and their use are actually so simplified that ordinary laboratory boys should be quite capable of making the routine observations; an intelligent man in charge of liming should have no difficulty in measuring the reaction of the heated juice and basing the liming on his results. To forestall the objection that someone is sure to make to this statement, it is obvious that none but an intelligent man should be permitted to have charge of the liming.

Insulation on settling tanks has usually been confined to covering the sides and seemed primarily for the purpose of preventing convection currents being set up by cooling at the sides. In the light of our new information, the writer feels that insulation becomes a matter of vital importance, especially in factories which are obliged to hold juice over for some twelve hours out of each day. An effective and economical way of insulating the bottoms of the tanks is to enclose the entire area with "Celotex," though a layer of asbestos on the cone would probably be well justified. For the tops a 2-3″ layer of asbestos plaster is recommended. With efficient insulation the temperature drop should be less than 0.5° F., per hour, which makes it possible to follow such a scheme as is outlined here. The importance of this phase of factory work has been so thoroughly demonstrated to the writer in the course of factory experiments this season as to prompt the expression of opinion that a very material possibility for increase in recovery lies open to most of the smaller factories at very small cost by proceeding in this direction. Nothing short of perfect conditions for juice preservation should be tolerated.

# pH and Turbidity*

By W. K. Orth

Only two members of our Association contributed to the report on pH and turbidity determinations. This is disappointing since the matter of pH measurement is of vital interest this year.

J. H. Pratt, of Pioneer Mill, considers the pH control of clarification as one of the most important advances we have made in the boiling house in recent years. He says: "From what we have done so far, I am convinced that we gained a lot of benefit." We, too, at Ewa, are certain that better clarification is due to closer attention to liming as a result of the pH determinations and turbidity measurements.

As routine, we determine pH values of the limed mixed juice and of the resulting clarified juice together with the turbidity figure in clarified juice every time a sample is taken as an average on 12 samples per day. Those interested are informed of the results as soon as possible, often over the phone.

The figures for mixed juice varied from 7.3 to 9.2, the low figure from 7.3 to 8.0 being recorded in 8 per cent of the samples, from 8.0 to 8.5 in 50 per cent, from 8.5 to 9.0 in 21 per cent, over 9.0 in 11 per cent of the juice tested. In the clarified juice the low figure was 6.9, the highest 8.2. It is 6.9—7.5 in 58 per cent, above in 42 per cent of the samples.

For thirty days, determinations were run on samples of all factory products as they follow each other in the process. The average figures found are:

| Mixed Juice | Clarified Juice | Syrup | A Massecuite | A Molasses | B Massecuite | B Molasses | 2nd Massecuite | Final Molasses |
|---|---|---|---|---|---|---|---|---|
| 818 | 7.61 | 7.51 | 6.84 | 6.76 | 6.76 | 6.77 | 6.70 | 6.33 |

Six tests were made to find if any deterioration took place during the boiling of low grade, with these results:

| Entering Molasses | After 2 hours boiling | 4 hours | 6 hours | 12 hours | After 7 days |
|---|---|---|---|---|---|
| 6.7 | 6.7 | 6.7 | 6.7 | 6.7 | 6.45 |

Glucose determination likewise did not indicate inversion.

A number of further tests are recorded, namely, averages of daily compilation of purities for mixed juice and clarified juice, CaO and $P_2O_5$ (grams per liter) in mixed juice and clarified juice, the increase in purity from mixed juice to clarified juice, and from mixed juice to syrup, the turpidity figure, the pH in limed mixed juice and in the resulting clarified juice.

Some of these follow. Attempts were also made to show the influence of $P_2O_5$ and CaO on pH determinations and turbidity measurements. By turbidity is meant a measure in degrees of millimeters, starting with zero and advancing to

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

higher figures with greater clearness of the liquid under observation. A higher "turbidity" figure means in our case clearer juice. The instrument used is the Kopke turbidimeter, consisting of a small graduated glass tube ⅛" in diameter and 6 cm. long, to the zero end of which is attached a white porcelain plate 4 cm. in diameter. This is marked with fine black lines, forming 2 mm. squares. This plate is immersed in the juice until the black lines become just invisible. The column of juice in the glass tube, corresponding to this point, shows on its upper end the turbidity figure.

| No. of tests | $P_2O_5$ grams per liter in mixed juice | pH difference mixed juice to clarified juice |
|---|---|---|
| 49 | .316 | 0.92 |
| 25 | .372 | 0.85 |
| 72 | .493 | 0.82 |

| $P_2O_5$ grams per liter in clarified juice | pH difference mixed to clarified juice | Turbidity |
|---|---|---|
| .0298 | 1.05 | 3.22 |
| .0350 | 0.91 | 3.37 |
| .0435 | 0.84 | 3.55 |

| $P_2O_5$ grams per liter in mixed juice | Turbidity | Tests |
|---|---|---|
| .289 | 3.10 | 20 |
| .324 | 3.30 | 83 |
| .403 | 3.61 | 60 |

| CaO grams per liter in mixed juice | Turbidity | Tests |
|---|---|---|
| .1626 | 3.34 | 48 |
| .2265 | 3.40 | 58 |
| .3045 | 3.58 | 19 |

| pH in mixed juice | pH in corresponding clarified juice | Tests |
|---|---|---|
| 8.03 | 7.22 | 30 |
| 8.22 | 7.48 | 68 |
| 8.68 | 7.65 | 50 |

The following shows the relation between $P_2O_5$ in mixed juice and corresponding clarified juice.

| $P_2O_5$ mixed juice | $P_2O_5$ clarified juice | Tests |
|---|---|---|
| .292 | .0214 | 30 |
| .304 | .0392 | 38 |
| .356 | .0433 | 38 |
| .459 | .0604 | 33 |
| .492 | .0696 | 30 |

| Purity of mixed juice | Turbidity | Tests |
|---|---|---|
| 81.2 | 3.38 | 25 |
| 83.4 | 3.46 | 35 |
| 84.8 | 3.57 | 38 |
| 85.7 | 3.65 | 18 |

| More CaO in mixed juice than in clarified juice | pH difference | Tests |
|---|---|---|
| .1227 | 0.82 | 33 |
| .1990 | 0.91 | 30 |
| .2645 | 1.03 | 27 |
| .3610 | 1.09 | 20 |

| Difference pH mixed juice to clarified juice | Increase in purity mixed to clarified juice | Tests |
|---|---|---|
| 1.01 | 1.72 | 20 |
| 0.97 | 1.89 | 35 |
| 0.81 | 2.07 | 40 |

The $P_2O_5$ content of the juice affects the turbidity as shown below:

| Mixed juice | $P_2O_5$ grams per liter Turbidity | Tests |
|---|---|---|
| .289 | 3.1 | 20 |
| .324 | 3.3 | 30 |
| .371 | 3.6 | 60 |
| .431 | 3.6 | 50 |
| .450 | 3.6 | 20 |

Mixed juices were limed to pH 8.6 in the cold, heated to boiling and then let stand in glass cylinders for varying periods of time, drawing the supernatant liquid off so as to show a progressive increase in clarity. The Kopke figure rises from 2.0 to 7.5, the pH of clarified juice remaning around 8.3.

In another test the Kopke figure in both the hot and cold juice rises from 2.2 to 4.7 with pH in the clarified juice 8.3. The purities rise in the first test from 85.05 to 86.63, in the second from 81.37 to 84.23. A general relation is clearly shown between increase in purity and turbidity. This is substantiated by figures over the whole season.

| Purity increase | Kopke |
|---|---|
| 0.86 | 3.3 |
| 1.82 | 3.5 |
| 2.53 | 3.6 |

Inasmuch as this turbidity is due to suspended precipitate in the juice which affects the Brix hydrometer, the purity changes must be so taken. Nevertheless, turbid juice must have some influence on the viscosity of low grade and on the filtration rate. The fact that we have drawn off juice from the top valves on the settlers, of Kopke between 6 and 7, yet rarely run over 4 in our composite, shows there may be room for improvement in that direction.

## Methods

The methods used at Ewa of estimation of hydrogen ion concentration have been various, new ones being tried as they became known, to find the best for our conditions. For the greatest part of the season, we employed the method described as follows:

Our method of estimating hydrogen ion concentration is based on the fact that the pH values are but slightly affected by dilution. Thus, taking juice as an example, if we dilute a given volume of juice with a given volume of distilled water and compare this with the same volume of juice diluted in the same proportion with buffer solution, using, of course, the appropriate indicator, we obtain a color match only if the pH of the juice and the pH of the buffer solution in question correspond.

The following remarks of S. G. W. Farrell, *International Sugar Journal*, Vol. XXVIII, p. 141, may be quoted here:

With buffered solutions such as cane juice, which contain protein, amino acid, amides, phosphates, etc., it is possible to dilute as much as 5 fold without appreciably altering the hydrogen ion concentration, particularly if this is in the neighborhood of pH 7.0.

Continuing the description of our method, if this is not so, we shall have varying shades depending on whether the pH of the buffer solution in question is above or below that of the juice. Since sugar house liquors in general show buffer action themselves, it is absolutely necessary that our standards be well buffered.

At the above mentioned place in the *International Sugar Journal,* we find:

In Natal, Uba juice is more buffered than the juice in Mauritius. In both countries there is an increase of hydrogen ion concentration between the cold limed juice and the hot clear juice. The average increase in pH is 0.6 for Natal and 0.3 for Mauritius:

Limed juice pH 6.9, clarified 6.3.
Limed juice pH 7.0, clarified 6.7.

The increase in hydrogen concentration is probably due to the coagulation of some of the albumen in heating. The albumen is the principal buffer in the cane juice, and when it is removed, there is greater association of the acids in the juice and its pH sinks.

To proceed with our Ewa method: Using clarified juice as an example, four drops of juice are dropped into each spot of a porcelain test plate, to one spot add 8 drops of distilled water (or better M/5 K Cl), to the others, add 8 drops each of buffer solution, covering the probable range, say, pH 7.2 to pH 8.0, in intervals of 0.2. Add one drop of 0.04 per cent phenol red solution, stir with a small glass rod and compare. One of the buffered solutions will match the unknown, or it will come between two of the buffered solutions, unless the range is incorrect. The drops must be uniform in size, as much as possible.

Our buffer solutions are made according to Clark & Lubs Standards, using phtalate—$NaO_4$ mixtures. This method is applied with variation to raw juice, syrup or even to molasses with some success. The accuracy depends entirely on the buffer solutions. Once standardized, this should not offer objectionable features. It is desirable to standardize them by the electro-metric method.

Our buffer solutions are made in concentration M/2 instead of M/5, as given by Clark. This is done because in some cases, the buffer action of mixed juice was strong enough to throw the M/5 buffers off for a wide range so that the pH determination became indefinite. We make indicators as described by Clark & Lubs, but in concentrations of 0.10 per cent and 0.05 per cent, corresponding to their 0.04 per cent and 0.02 per cent. The reason is that only one drop is needed.

This method which was worked out with great diligence and care by our Mr. Bond, gave indeed very satisfactory results, but we admit is more difficult of application for the average sugar laboratory than the method sent to the plantations by the Experiment Station, H. S. P. A.

Their first set of color charts was carefully compared with our system with the following results:

| 2 Observers | 1st Day | 2nd Day | 3rd Day | 4th Day | 5th Day | 6th Day | 7th Day | 8th Day | 9th Day | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|
| Max. Variation, H. S. P. A..... | 0.2 | 0.3 | 0.1 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 |
| Max. Variation, Ewa ..... | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Variation, Ewa-H. S. P. A. | 0.5 | 0.7 | 0.4 | 0.5 | 0.6 | 0.8 | 0.4 | 0.7 | 0.6 | 0.6 |
| Mix. Juice Avg., H. S. P. A..... | 8.0 | 8.4 | 7.5 | 8.4 | 8.4 | 8.5 | 8.4 | 8.4 | 8.2 | 8.24 |
| Clar. Juice Avg., H. S. P. A..... | 8.1 | 7.3 | 7.1 | 7.2 | 7.4 | 7.3 | 7.7 | 8.0 | 7.7 | 7.53 |
| Mixed Juice, Ewa ..... | 8.1 | 8.8 | 7.3 | 8.7 | 8.7 | 8.8 | 8.6 | 8.5 | 8.4 | 8.43 |
| Clarified Juice, Ewa ..... | 8.4 | 7.2 | 6.9 | 7.1 | 7.1 | 7.3 | 7.8 | 8.2 | 7.9 | 7.54 |
| Number of Tests | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 4 | 38 |

We continued to prefer our method. But, when buffer solutions were re-standardized by the new potentiometer at the Experiment Station and, after new charts had been furnished, the results of comparisons were much closer and quite satisfactory:

| DURING DAY | | | | | | | | DURING NIGHT | | | | Observer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | 2 | | | | 3 | | | | |
| Ewa | | Exp. Stn. | | Ewa | | Exp. Stn. | | Ewa | | Exp. Stn. | | 50 Tests |
| Mix. | Cl. | Mix. | Cl. | Mix. | Cl. | Mix. | Cl. | Mix. | Cl. | Mix. | Cl. | |
| 8.33 | 7.35 | 8.33 | 7.39 | 8.22 | 7.36 | 8.24 | 7.39 | 8.24 | 7.15 | 8.22 | 7.13 | |
| Same juice | | | | Same juice | | | | Same juice | | | | |

Toward the end of the season we received a La Motte Hydrogen Ion Comparator set with the following standards:

| | |
|---|---|
| Brom cresol purple | 5.4—6.6 |
| Phenol red | 6.8—8.4 |
| Phenol blue | 8.0—9.6 |

The whole outfit with 30 standards, graduated test tubes and graduated trappers plus comparator box cost but $9.00.

The results with this apparatus were very satisfactory and the closest concord between the different observers was found. As the apparatus was in use for only three weeks, a final judgment cannot be given. It is very promising.

In the *International Sugar Journal* of May, 1925, are found descriptions of H. C. Prinsen Geerligs and Prof. Dr. Herzfeld, for the use of test papers with the following indicators:

Brom cresol purple, brom thymol blue, corallin and phenol red. Dr. Herzfeld indorses this method as much simpler than determination of pH values described by American chemists, using buffer solutions. The papers are used in factories that employ the carbonatation process, where a close observance of the "end points" is essential.

We, at Ewa, have tried home-made brom cresol purple and phenol red paper, so far, in a desultory way, with disappointing results. We intend to test the possibilities in a more whole-hearted way during next season.

Finally, I beg to mention the latest directions sent out by the Experiment Station, dated July 22, 1925. They are so complete and so easy to follow that every laboratory should have something to say on pH determinations for the meeting of next year.

The reports of J. H. Pratt, of Pioneer Mill Company, F. D. Bolte, of Hutchinson Sugar Company, and E. Haneberg, of Olowalu Company, follow. I have no other comment to make, but to say that they are very interesting and highly welcome to fill my meager paper.

Mr. Pratt comments as follows:

We used pH control during the last thirteen weeks of the crop. Comparisons between this period and the other two-thirds of the year are not very satisfactory, mainly for two reasons. The rate of grinding started to slow up soon after this work was started. Out of an available 75 days, we ground on 69 and only averaged 17.2 hours per day. In June, we encountered four or five fields, the juice from which was very difficult to handle at both the settling tanks and presses and which, for several weeks, almost doubled our usual percentage of mud on cane. My comparisons are, therefore, based on the first five weeks that we had this work on a routine basis and before either of these difficulties became serious.

It took almost two weeks to educate the men at the liming and settling tanks to the meaning and importance of the pH figures, but, after this, the results of the work were immediately apparent. During these first two weeks, 72.3 per cent of the settling tanks were 7.7 pH or higher, while during the succeeding five weeks the percentage rose to 94.5. The rise in purity from the mixed juice to syrup showed an increase of .3, the purities of the individual syrup and clarified juice samples were much more consistent than heretofore, the amount of lime used went up 13 per cent and the amount of press cake showed a corresponding increase (12 per cent). The polarization of the mud showed a decrease of .1.

During the thirteen weeks, we tested 2257 settling tanks (92 per cent of the number filled), 530 samples of "cold limed juice," 683 press juice, and 437 of syrup. This gives an average of two clarified juice samples an hour, 1 mixed and 1 press juice every two hours, and a syrup every three hours. The juices are all grab samples, while the syrup is our regular three-hour composite (without formalin). We use a dilution of from 1 to 3½ or 4 for the juices and of 1 to 16 or 20 for the syrup. During most of the period, these dilutions were made with distilled water. As this was always slightly acid, it was found to be quite as simple to neutralize ordinary tap water. Our tap water reads about 7.8 pH.

Owing to the amount of color in our massecuites and molasses, we found it very hard to get accurate readings without very high dilutions. The few samples which we were able to read at 1 to 50 dilutions, gave the following results: "A" molasses 7.28, "B" molasses 7.18, "C" molasses 7.10, and waste molasses 7.00 pH. Our low grade sugar is also about 7.0 pH. Twelve samples of wash water from the presses averaged 7.8 pH.

A very important use of these indicators is in testing the liming of tanks of juices which are to be held over shut-downs. The first four weeks that we were using the pH sets, the juice held over Sundays dropped from 8.43 to 7.32 (on the clear or filtered juice) in 25 hours. By testing every tank that was to be held over a shut-down or even a couple of hours, we were able to keep the juice held over at about the same pH as when running steadily. Quite often we tried the pH of the juice at intervals of three or four hours during a long shut-down. The average of 107 tanks which were held over a period of at least three hours longer than the usual settling time was 7.50, and omitting the samples from the first few weeks, would considerably improve this average.

The following are the weekly averages of our samples:

| Week ending | Clarified No. | Clarified pH | Limed No. | Limed pH | Press No. | Press pH | Syrup No. | Syrup pH |
|---|---|---|---|---|---|---|---|---|
| April 11..... | 156 | 7.79 | 8 | 8.84 | 3 | 7.47 | 28 | 7.69 |
| " 18..... | 151 | 7.77 | 25 | 8.83 | 7 | 7.60 | 30 | 7.67 |
| " 25..... | 217 | 7.98 | 31 | 8.85 | 29 | 7.81 | 39 | 7.75 |
| May 2..... | 192 | 8.00 | 38 | 8.89 | 43 | 7.78 | 42 | 7.74 |
| " 9..... | 193 | 7.94 | 50 | 8.85 | 50 | 7.77 | 43 | 7.69 |
| " 16..... | 163 | 8.00 | 90 | 8.88 | 78 | 7.76 | 34 | 7.64 |
| " 23..... | 189 | 7.93 | 67 | 8.87 | 63 | 7.76 | 37 | 7.49 |
| " 30..... | 228 | 7.94 | 60 | 8.95 | 106 | 7.81 | 39 | 7.55 |
| June 6..... | 151 | 7.90 | 12 | 8.83 | 53 | 7.67 | 23 | 7.42 |
| " 13..... | 184 | 7.92 | 35 | 8.89 | 78 | 8.05 | 33 | 7.57 |
| " 20..... | 155 | 7.82 | 30 | 8.92 | 69 | 7.78 | 32 | 7.56 |
| " 27..... | 194 | 7.73 | 63 | 8.95 | 81 | 7.64 | 46 | 7.52 |
| July 1..... | 84 | 7.83 | 31 | 8.69 | 23 | 7.64 | 11 | 7.52 |
| True Average.... | 2257 | 7.90 | 530 | 8.88 | 683 | 7.78 | 437 | 7.61 |
| Arith. Mean .... | | 7.890 | | 8.865 | | 7.733 | | 7.600 |

I consider that pH control of clarification is one of the most important advances we have made in the boiling house in recent years.

Mr. Bolte's report follows:

We have been determining the pH values of our clarified juice, press juice and syrup with the four indicators and color charts furnished us by the H. S. P. A., Experiment Station, since May of this year, i. e., brom thymol blue, phenol red, cresol red and thymol blue.

A request for an indicator and chart of higher pH range, say, methyl red or brom phenol blue, with pH ranges from 4.6 to 6.0 and 3.0 to 4.6, as given by Clark and Lubs on page 80 (Table 6), was turned down by the Experiment Station, and we have not procured buffer solutions to make a scale for ourselves yet.

With the above available four indicators, we have determined the pH values regularly on our regular 3-hour composite samples, and below you will find the average pH values for the three juices tested, viz.:

| Month | Clarified Juice | Press Juice | Syrup |
|---|---|---|---|
| May ..... | 7.34 | 7.56 | 7.07 |
| June ..... | 6.86 | 7.17 | 6.71 |
| July ..... | 7.03 | 7.19 | 6.87 |
| August ..... | 7.09 | 7.43 | 7.02 |
| True average ..... | 7.09 | 7.35 | 6.92 |

We have endeavored to lime our mixed juice to a slight phenol alkalinity at the juice scales, or to 8.4 pH, resulting in above values for the subsequent juices.

We found at first that the formaldehyde added to the sample buckets to preserve our juices gave us wrong pH values, so we discontinued adding formaldehyde to our sample buckets with no influence on our purities and giving us correct pH values from our regular composite juice samples.

Turbidity determinations with the Kopke turbidimeter have been made here for the last two years regularly on all our juice samples with these results:

| | Clarified Juice | Press Juice | Syrup (Dilution 1/5) |
|---|---|---|---|
| Average for 1924-25 | 2.76 | 3.70 | 1.75 |
| January to March | 3.02 | 3.81 | 1.77 |
| April | 3.68 | 3.96 | 1.93 |
| May | 4.09 | 6.11 | 2.68 |
| June | 3.63 | 4.34 | 2.62 |
| July | 2.95 | 3.36 | 2.31 |
| August | 2.47 | 3.17 | 2.06 |
| True average (to date) | 3.21 | 3.93 | 2.19 |

Better turbidity figures for 1925 against 1924 are due principally to grinding more Yellow Caledonia cane this year, against more Rose Bamboo cane last year.

| | Per Cent Yellow Caledonia | Per Cent Rose Bamboo |
|---|---|---|
| 1924 | 37 | 63 |
| 1925 (to date) | 64 | 36 |

The juice of Yellow Caledonia cane clarifies better than that of Rose Bamboo cane, due to a much higher phosphoric acid content, and requires more lime for tempering than do the juices of Rose Bamboo.

The average phosphoric acid content of juices for 1925 follows:

| | |
|---|---|
| Yellow Caledonia cane | 0.063% |
| Rose Bamboo cane | 0.027% |

Regarding improvements on the methods, would suggest that the Experiment Station prepare and furnish methyl red and brom phenol blue indicators and color charts for the determination of higher pH values in unlimed mixed juice and field juices, too.

Mr. Haneberg submitted the following report:

I am enclosing herewith a tabulation of all my data on temperature drop in juices held over and on the pH drop. I have no record of the atmospheric temperatures and wind conditions which perhaps would explain some of the differences in drop per hour on consecutive days.

You will also find it strange, as I do, that the average drop in pH is not proportional to the drop in temperature. For instance:

No. 5 shows an average temperature drop of 0.397 and pH 0.511.

No. 4 shows an average temperature drop of 0.452 and pH 0.499

I can only assure you that readings were taken very carefully and with the expectation of having them doubted.

We proved to our own fullest satisfaction that the old bagasse filling was a better and far less expensive insulation than the 85 per cent magnesia blocks, which appear to be inferior to Celotex fiber board.

Of course, it is necessary to remove the bagasse every 3 and 4 years and to paint the tanks, but that must also be done with magnesia insulation if any moisture gets into it.

Our tests further proved conclusively that it is absolutely necessary to cover the tops of the tanks to prevent an excessive drop of temperature. We have spent, annually, about $400 for formalin, and since we have covered the tops of our tanks, we have not used a drop of it.

A tabulation too long for publication gave some interesting data on temperature drop over the hold-over period, with pH measurements on the same juice. A digest of this data follows:

TEMPERATURE DROP F° PER HOUR

| | Settling Tank Number | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| March 27 to April 7, 1925..... | .41 | .36 | .44 | .34 | .27 | .50 |
| May 6 to June 8, 1925..... | .62 | .52 | .52 | .45 | .40 | .54 |

All tanks in T. & G. casing, with 4" layer of bagasse surrounding.

During the second period, tank No. 1 was covered with 1½", 85 per cent magnesia blocks; No. 2 was covered with three ½" layers of Celotex bagasse board and wood lagging.

In all cases, juice temperature was reduced to 180-200° F.; juice reaction was carried to show phenolphathalein alkalinity and the reaction of the juice was uniformly satisfactory at the end of the hold-over.

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# Short Term Contracts on Hawaiian Plantations*

By J. H. Midkiff

Labor is one of the greatest, if not the greatest, items of expense on all the Hawaiian plantations. From the time the land is cleared and the breaking plow turns the first furrow in preparation for the planting until the bagged sugar is shipped from the plantation, the problem of doing every operation as cheaply and economically as possible is extremely important. In fact, the difference between a profit and a loss on the sugar produced rests, to a very great extent, in the hands of the men who are handling the labor.

Satisfactory handling of labor is particularly difficult at this time for two reasons: first, labor is universally demanding more and more for what it does (and Hawaii is no exception to this rule), and, second, the prices that can be obtained for sugar at present make it necessary to do our work cheaper than formerly, if we hope to keep the red ink off our books.

It is probably not self-satisfaction for us to say that Hawaii leads the world in efficient sugar production. Results show that nowhere else can such large returns per acre be found as are common today in Hawaii. Our systems of cultivation, our knowledge of fertilizer and water requirements, our methods of combating insect pests, plant diseases, etc., all show that much time has been spent to good advantage in solving those problems. But it might be pointed out that we have not been quite so successful in improving our methods of handling labor.

Suggestions for improving labor conditions have not been altogether lacking, either. Labor unions and labor agitators simply say: "More pay and shorter hours is all that is needed." They are looking at one side of the question only. They do not realize that many times an increase in rates, *without a proportionate increase in results,* would be absolutely disastrous to the employers. Employers, on the other hand, have also often been to blame in that they have not given enough thought to methods of bettering labor conditions. Sometimes labor can be given a chance to

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make more without raising the net cost of the finished product. *Changes that affect labor must be mutually beneficial to the employers and the laborers if they are to be really and permanently successful.*

### Day Work Labor

For many years a large part of our plantation work has been done by day labor. An overseer in charge of a gang simply got what he could out of the men. While good work can be done in this manner, the system is expensive, even though the base rate per day may be fair, because the incentive for any man to do more work than any other man is lacking. It is the natural thing for the average worker to get through the day as easily as possible, doing no more work than he has to, to "get by" with the overseer. Under these conditions, it is a pretty good testimony to the efficiency of the overseer when good, economical work is done.

### Long Term Contracts

The cultivation, that is, the weeding and irrigating, of the growing cane crops has been done in Hawaii for a good many years past by long term contracts. Certain men are given so many cents per ton to cultivate a given area of cane, usually from the time of the second or third irrigation until the water is taken off of the crop. On unirrigated cane the labor is continued, of course, until the cane has reached maturity.

The long term contract is good because it furnishes an incentive to the men to do good work and to stick to the job until the crop is produced. Every one realizes that the better he works and the more cane he raises, the more money he makes. It is doubtful if, under our present labor conditions, a better system of cultivating the cane than this will be found.

But there are hundreds of jobs on a plantation that can not be included in the long term contract. The planting of the cane, getting a field in condition to give to the long term contractors, extra help in hoeing the cane when the work is so great that the long term contractors can not handle it all, ditching, fencing, harvesting, and many other jobs, all have to be done by some system other than by long term contract.

### The "Ukupau" System

To get these many jobs done as efficiently as possible, someone hit upon the "ukupau" system a few years ago. By this plan the men are told that they may go home as soon as they have done a certain definite amount of work—hoed so many lines of cane, or dug so many post holes, for instance. This system had a very strong appeal to many of the Filipinos in the early days. Getting home early, a few years ago, seemed to be more of a consideration to them than earning more money. But as the proportion of family men increased, and as a better class of men of this nationality began seeking employment here, higher pay became more important to them than simply going home early.

### The Short Term Contract

The short term contract, or the individual contract, whereby each individual man is paid for what he himself actually does, regardless of the pay of the other

men in the gang, is a natural step in the right direction; a system whereby an attempt is made to help the men who want to help themselves; a method of giving men a chance to receive more money, provided they in turn are willing to produce more for the plantation.

To find out just how far this short term contract system has advanced throughout the Territory, questionnaires were sent to all the agricultural members of the Association of Hawaiian Sugar Technologists, asking them to give their rates, opinions, and suggestions for improving short term contracts. The concensus was that the short term contract is the solution to our greatest labor problem. In the following paragraphs are the reasons advanced by these men, who are handling a large part of the labor on our plantations, why short term contracts are good. The opinions given by other men are in quotation marks.

### Reasons Why Short Term Contracts Improve Our Labor Conditions

1. There is a greater incentive for laborers to work harder and earn more money.

2. A good laborer gets what he himself actually earns. His earnings are not held down by loafers or malcontents in the gang.

3. Short term contracts are cheaper for plantations, because:

   A. Fewer men do more work and the overhead is cut down.

   B. Important work is done in a shorter time. Often a weeding, for instance, speeded up by contract, gives the cane a longer and better growing period uninterrupted by weeds.

4. "Fifty per cent more work accomplished."

5. "I believe short term contract to be the best. It takes less supervision and gets more work out of the men. At the present time Filipinos seem to take more to ukupau or day work, but I believe this will change as soon as they get onto the work and get a better idea of what a job is worth."

6. "The main advantage in short term contract is that the men work harder, therefore get the work done faster. Even though the cost per acre is the same as ukupau or day work, you are able to get more work done in the same length of time."

7. "Use short term contract where possible (except in irrigation, which should be long term contract). One-third more work is gotten from men who have something to work for. There are no special drawbacks, provided men have a reasonable price for their work, a good luna to see that the work is reasonably well done, and one who can keep them interested in their work."

8. "Puts laborer on his own. Short term contracts help in keeping good loading and cutting gangs together in the off-season."

9. "The advantages of short term contract are the ability to get work done faster with fewer men, thus getting over your fields oftener and, also, probably creating a better feeling among the laborers, as they not only make more money per day but get home earlier. This getting home early is one of the main factors with the Filipino."

10. "Men work harder. The pay is better distributed. Have chance to weed out poor men. Overseers watch class of work and do not have to urge men on."

11. "My records show that short term contracts have given us a gain of 20 to 25 per cent increase in daily work per man with a reduction in cost per unit of 10 to 12 per cent."

### Disadvantages of Short Term Contracts

It is unreasonable to suppose that all men should see things in the same light. In the following paragraphs are quoted a number of objections voiced to short term contracts. But most of the men answering these questionnaires, even though they pointed out the following drawbacks, were in favor of the new plan. Here is what they said:

1. Men get to liking short term contracts so well they do not like to take the all-important long term contract.
2. "Apt to be kapulu or careless."
3. "Have found contract plowing and mouldboarding very irregular."
4. "Requires more supervision by section lunas."
5. "Where we have no long term contracts, we find short term contracts in big cane are unsatisfactory. Last year we let out quite a number of contracts at from $1.00 to $1.50 per acre, but found that the men were inclined to take too much water and waste a lot. Where we have to pay for water, we find it cheaper to do this job by day work."
6. "The drawbacks are rough work and the inefficiency of plantation lunas to give correct rates."
7. "When labor is plentiful we believe we get better work by day work than by contract as far as cultivation work goes. Our experience with short term contract hoeing, for instance, is that you get more work out of the men but the work is not done as well as by day labor. The second hoeing has to be done much earlier when the first hoeing was done by contract. We would prefer the ukupau system rather than fixing a rate so much per acre."
8. "The disadvantage is usually poorer work, as the men are hurrying over the job in an effort to get the most they can. In plain words, the main trouble is 'kapula' work, as the main effort is quantity, not quality.'
9. "Requires close supervision to check overseers. Uneven conditions make it hard to determine price."

### Suggestions For Improving Our Methods of Handling Short Term Contracts

A great many valuable suggestions were given in the answers received for successfully carrying on work under the short term contract system. The following pointers will apply to most places and conditions in Hawaii:

1. Always give the rate before the work is started and stay by the rate when it is too high. Use your experience and better judgment in giving a fairer rate next time.
2. "Many more jobs than are now done by short term contract could be done by this method if a contract rate book is kept in the plantation office and all details of the conditions of the job entered alongside of the job and rate. This book could then be consulted by anyone on the plantation to secure the proper rates. Several plantations now do this."

3. "Have good, honest, and conscientious field and gang lunas."

4. Give rates for the job sufficiently high to be an incentive to work hard and not rates whereby the laborer, even though he "sweats his brow off" can not make more than day wages, and thereby becomes discouraged.

5. "Regarding short term contract, I want to say I am a strong backer of this system, so much so that about 75 per cent of the work done under my supervision is handled in this way. I find it to be a great labor saver and also helps to cut down costs of cultivation."

6. "Of all short term contracts I believe a weeding contract to be the most difficult to give correctly. While other contracts, such as planting, cutting, or loading cane, may vary a few cents per ton or a dollar or so per acre, a weeding contract may be worth anywhere from $1.00 to $20.00 per acre.

"A luna can not go into a field and simply by looking at the grass say how much it is worth. A weeding rate can not be guessed at, if you expect to get the most out of your men, as they know you are only guessing and will work slowly with the idea of getting a higher rate. Only men who know the game should be allowed to give out weeding contracts, and a little extra time spent arriving at a rate that is more or less correct is time well spent and has a mighty good effect upon the men, and then they know you are not guessing.

"The way I arrive at a rate is to take one man from the gang, not the best man—just any one I happen to pick. With my watch in my hand I time him on two or three lines or more, then I take his average time per line, say it is 10 minutes. Then he will do, at this rate, 6 lines per hour. If he works 10 hours per day, he will do 60 lines. I usually take off about 10 lines to allow for level ditches. That would make 50 lines per day per man, or at the rate of about 5½ men per acre, if the lines are 30 feet. In this instance, I would offer then $7.00 per acre, with the idea of letting them "Jew" me up to $8.00, which would be about right, and they would feel that they were working at their own figure, which has a very good effect on them. A contract given out in this way seldom goes wrong."

7. "Get dependable contract bosses."

8. "For short term contracts in irrigation, it is very important to have a good water luna in the field to see that the men do not take too much water and break things up."

9. "The way I believe short term contracts can be improved is to have one experienced man in charge of all contract work. Spend enough time with the men to arrive at the correct rate, and pay them what they make. Never cut them down after you have set the rates. But the main thing is to have a good man to take charge of the work, especially one the men have confidence in and know they are going to get a square deal."

10. "While in charge of tunnel construction I have used a short term contract that worked out very well. It had been customary to give out each tunnel, regardless of its length, at a certain price per foot. The contractor, who hit easy going, made a lot of money, while the one that hit it hard and saw that he was going to lose out, usually folded his tent and disappeared, leaving us in the lurch. So I started giving a flat rate for a certain number of feet, depending upon the material they were in at the time. If it was hard material, 25 or 50 feet was

about the limit. If it was softer, such as soft dirt, I would give them up to 200 feet, but usually they were satisfied with about 100, as they were afraid of it getting hard.

"This system is a very interesting gamble and it made a big hit with them. It also protected the contractor as well as the company. If they lost, the losses were light. If they were lucky, they did not make too much. It all depended upon the run of material, and was an even break. If they hit it hard just before their contract ran out, they would work their heads off so they would not lose too much. On the other hand, if they hit it easy there was great rejoicing but no slacking up in the work."

11. "The best suggestion I could make is to put all men on their own, take them out of a gang and have good lunas with not too many men under them. About 20 men is the most a luna can handle and keep his lines straight. If a section overseer places a rate on a field and it is too high he should let it go that day, for if he should change it the labor would lose confidence in him. The men will know if the rate is too high and will take the cut the next day and be satisfied."

12. (a) "Always fix the price before men commence their task and keep them to that price no matter how much or how little they make. Price should be set by a responsible overseer.

(b) "Gangs should never be more than from twenty to thirty men.

(c) "Have a good luna:

(1) Who is capable of seeing that men make a reasonably good job;

(2) Who can demonstrate to men in a satisfactory way;

(3) Who can send the slackers of the gang about their business.

12. (d) "When commencing a new task, if men are shown what is wanted during the first hour, I have found that this is more than half the battle."

13. (a) "For weeding and hoeing, if rough work is being done, send them on day work for a while with a luna at day rates.

(b) "For cutting cane, especially with Filipinos, I got good results last year by having an expert cutter show every man the proper method of cutting and piling at the flume. If I found a rough cane cutter after that, I put him in the day work gang. We had good clean fields last year compared with previous years.

(c) "Pay enough on hoeing. If you stint them you are liable to get poor work.

(d) "Select the very best men for contractors. Men who are leaders. Don't fool around with a weakling or a man who won't dirty his clothes. It doesn't pay."

## Rates Vary With Conditions

In the following tables are given some of the rates paid for various jobs. These rates are simply the amounts paid to the laborers. They do not represent the total cost to the plantation, because they do not include overhead, supervision costs, material, etc.

It must be understood at the beginning that it is absolutely impossible to fix one set of rates that will apply to all conditions throughout the Territory, or even to all fields on the same plantation. For this reason rates quoted by men on each of the four main islands are listed separately.

RATES:

| JOB | OAHU | MAUI | KAUAI | HAWAII |
|---|---|---|---|---|
| **Steam Plowing** | $3.50 to $4 1st plowing. $3 to $3.50 per acre 2nd plowing. | | | Next year trying steam plowing by short term contract. |
| **Tractor Plowing** | $2 per acre with 60 h. p. tractor and 4-disc plow. | | $3 to $4.50 1st and $2 to $4 2nd plowing. | Fordson $3 to $5 per acre. |
| **Harrowing** | | | | |
| A—Tractor | | | | $1 to $2 per acre. |
| B—Mules | | | | $2 to $3 per acre. |
| C—Steam plow | 50c per acre | | 35 to 60 cents per acre. | |
| **Mouldboarding** | | | | |
| A—Tractors and 1 plow | $2 per acre. | | $2 per acre. | |
| B—Tractors and 2 plows | $1.75 per acre. | | $1.50 per acre. | |
| Mules | | | $3 to $4.25 per acre. | $2 to $4 per acre. |
| **Preparing Lines** | | | | |
| A—Plow (1 mule and canoe plow). | 75c per acre. | | | $1 per acre, small plow with two mules. |
| B—Hoes | $1.25 per acre. | | ½ to 1½c per line. | ⅓ to ½c per line of 33 feet. |
| **Planting** | | | | |
| (a) Acre | | $6.50. | $10 to $12, including 1st water. $6 per acre on unirrigated land. | $4.25 to $4.50 on unirrigated land. $5 to $8 per acre, including preparing with hoes. |
| (b) Bag | 3c to 8c per bag, depending on amt. of preparing necessary and amt. seed is lapped. | | | |
| (c) Marking watercourses | | | 25c per acre. | |

| JOB | OAHU | MAUI | KAUAI | HAWAII |
|---|---|---|---|---|
| **First Irrigation** | 1¼c line. 1½c line with trash panis. | 1 to 1½c line with panis. 1c line no panis. | $2.50 acre no trash, $3 acre with trash. | $4.50 to $5.50 including trash, panis, and cleaning level ditches. |
| **2nd Irrigation** | ¾c line | ½ to ¾c line, taking two watercourses. | | $2.25 per acre.<br>$2.00 and $1.75. |
| **3rd Irrigation** | ¾c line | ¾c line. | | $1.75 per acre. |
| **Later Irrigation** | | | | ½ to ¾c line. |
| **Making trash panis in bundles** | | | 30c per 100 panis. | |
| **Hoeing** | | | | |
| A—Light grass | ¾c to 1½c line. | 1 to 2c line. | $4 acre, ½ to 2c line | $3 to $4 per acre.<br>From $6.50 per acre up. |
| B—Medium grass. | 1½c to 2c line. | 2 to 4c line. | $7 to $8 acre, 2c to 4c line. | $4 to $5 acre.<br>$5 to $6.75. |
| C—Heavy grass. | 2½c to 5c line. | Up to 10c line.<br>3 to 6c line. | $10 to $12 per acre.<br>4c a line and up. | $5 to $8 acre.<br>Up to $10 acre.<br>$7 to $8.50 acre. |
| **Carrying Seed for Planting With Pack Saddles.** | ¼ to ½c per bag, depending on distance, character of land, etc. | | ½ to ¾c per bag. | $1 to $3 per acre, depending on nature of land, length of pack. |
| **Cutting Seed** | | | | |
| A—Top | 10c for 70 lb. bag. | 10 to 15c bag, 135 seeds in a bag; 8 to 12c, 125 seeds. | 10c per bag ahead of cutting, 8c behind; 9c including packing to cars. | 8½ to 13c, depending on variety and tasseling; 70 lb. bags.<br>$2.50 ton. |
| B—Body. | 5c for 70 lb. bag. | 4 to 7c bag of 135 seeds. | 6c bag.<br>5c for 60 to 70 lb. bag. | |
| Size of bags. | | | | 25 to 35 bags per ton. |

| JOB | OAHU | MAUI | KAUAI | HAWAII |
|---|---|---|---|---|
| **Digging Out Track Lines** | 1c per line, 3c for main lines. | 1c line where track crosses furrows, 3c where track runs full length of furrows. 5c for main lines. | $3.00 per acre for all tracks. | |
| **Palepale** | 1c line | $2.25 to $2.50 acre. | 1c line. | $1.50 to $2.50 per acre. |
| **Cutting Back** | | | | |
| A—Hoes | | 75c to $1.00 per acre. | $1.00 per acre on ratoon cane. | |
| B—Knives | $1.25 per acre. | ½c line and tops put in watercourse. | $1.00 per acre on plant cane. | |
| **Fertilizing** | | | | |
| I. Nitrate of Soda. | | | | |
| (a) 3 bags per acre. | 20c bag. | | 30c bag. | |
| (b) 4 bags per acre. | 18c bag. | | 22c bag. | |
| (c) 5 bags per acre. | 15c bag. | | | |
| II. High-Grade. | | | | |
| (a) 3 bags per acre. | | 13 to 15c. | | 12c bag and 10c additional for each bag over 12. |
| (b) 4 bags per acre. | | 10 to 13c. | | |
| (c) 5 bags per acre. | | | 15c bag, including carrying in. | |
| (d) 6 bags per acre. | 10c. | | 10c. | |
| (e) 8 bags per acre. | 9c. | 9 to 10c. | | |
| (f) 10 bags per acre. | 9c. | | | |
| III. Rock phosphate thrown broadcast on plowed land —5 bags per acre. | | | 5c per bag. | |
| IV. Washing fertilizer bags. | 20c per 100 bags. | | | |

| JOB | OAHU | MAUI | KAUAI | HAWAII |
|---|---|---|---|---|
| **Laying Portable Track** | 23c per section. | 6c a ton.<br>5c a ton on flats, 7c a ton in rocky land, 4½c in machine loaded fields. | 10c per rail, 12½c for heavy rails. | |
| A—Putting in switches. | | | 35c. | |
| B—Laying portable flume. | | | | 4c to 7c per ton of cane flumed. |
| C—Packing for fluming. | | | | 14 to 16c ton. |
| D—Putting cane in flume. | | | | 14 to 17c ton. |
| E—Loading flume cane in cars. | | | | 4 to 5c ton. |
| **Small Cane** | Add 4 to 6c per car and let hapaiko men pick it all up. | $1.00 per ton. | $1 to $1.30 per ton. | |
| **Cleaning, Scraping and Painting Rails After Harvesting** | | | 32c per section. | |
| **Hilling-Up with Mules** | $6 acre for 4 times small plow and 1 time mould board. | | $5 per acre running 3 times with 6″ plow and once with clean plow. | |
| B—"Hukilepo" after hilling-up. | 1c to 1½c per line. | $3 to $4 per acre. | $2.50 to $3.50 per acre. | |
| **Stripping Cane** | | | | $4 to $5 per acre. |
| **Cutting Cane Tops** | 75c car. | | | |
| **Clearing Land** | | | | |
| A—Heavy Lantana. | | | $15 to $20 per acre. | |
| B—Stones. | | | | $8.50 per acre, including clearing ends of fields. |

| JOB | OAHU | MAUI | KAUAI | HAWAII |
|---|---|---|---|---|
| **Digging Drain or Irrigation Ditches** | | | | |
| 1½ ft. x 1½ ft. | 2c ft. | | 30c cu. yd.<br>3c ft. | |
| 2 ft. x 2 ft. | 3c ft. | 3 to 4c foot. | 4 to 5c ft.<br>3c per ft. | 2c ft. and 4c ft. in rocky land. |
| 3 ft. x 3 ft. | | | 8 to 10c foot. | |
| 2½ ft. x 2½ ft. | | | | 3½ to 5½c per ft. |
| 14 in. x 21 in. | ¼ to ½c ft. | | | 2 to 3 cents. |
| **Cleaning Level Ditches** | | | ½c foot. | |
| **Putting in Water Gates** | | Small gates 40c. Large gates 75c. Large boxes $1.25 each. | 35c per gate. | |
| **Loading Dirt on Cars** | 75c car. | 25c yard. | | |
| **Loading Sand** | 30c car. | | 20c yd. | |
| **Unloading Sand** | 15c car. | | 10c yard. | |
| **Loading Rock** | 12c ton. | 14c ton. | | |
| **Unloading** | | | | |
| (a) Mudpress. | 37c car. | 20 to 25c car on main line. 15c car dumping in irrigation ditch. | 25c car. | 50c ton unloading and spreading. |
| (b) Manure. | | | | $1 per ton, 25c per wagon. |
| Unloading 320 bag cars of fertilizer into warehouses. | | | $3 per car. | |

| JOB | OAHU | MAUI | KAUAI | HAWAII |
|---|---|---|---|---|
| **Making Fences** | | | | |
| (a) Single wire fence to keep cane up. | 12c per post, wire included. | | | |
| (b) | 7c per ft. for dipping posts, digging holes, making gates and putting up woven wire fence. | | | |
| (c) Dipping posts in creosote solution. | | | ½c per post. | |
| (e) Digging post holes. | | 3c for 2 ft. hole, 5 to 8c in rocky land. | | |
| **Painting House** (Costs figured on square feet of floor space). | | | | |
| (a) By hand. | Inside 2c.<br>Outside 2c. | | | |
| (b) By electric portable paint machine. | 1c sq. ft. | | | |
| **Cutting Wood** | | | | |
| A—General. | | $1.55 cord. | $1.50 cord. | $2 to $2.50 cord. |
| B—Eucalyptus. | $2 per cord. | $1.65 cord and 35c for loading and hauling to main line. | | |
| C—Plum. | | | $1.20. | |
| D—Pine. | | | $1.50. | |
| E—Koa. | | | $1.35. | |
| F—Ohia. | | | | $4.50 cord. |
| **Planting Trees** (including digging hole and giving first irrigation). | | | 3c each. | |

| JOB | OAHU | MAUI | KAUAI | HAWAII |
|---|---|---|---|---|
| **Stone Ditches** | 2 stone, 60c ft.<br>3 stone, $1 ft. | | | |
| **Cement Ditches** | | $2.70 ft. for 7′ x 2′ x 2′ ditch, including material. | | |
| **Laying Concrete Pipe Ditches** | 8c ft. | | | |
| **Tunneling** | | | | |
| 1st 100 feet. | In soft rock $2.50 per yard. In hard earth, $1.50 per yard. | | In soft dirt 60c cu. yd. for 1st 100 ft. and additional 15c per yd. for each 100 ft. additional. | |
| Breaking Rock. | 65c yd. breaking and loading on cars. | | 50c yard. | |
| **Digging Cesspools** | | | | |
| 6½ ft. x 6½ ft. and 10 to 13 ft. deep. | Soft earth $5 to $7.<br>Rock dirt $7 to $12. | | | |
| **Paper Mulching** | | | | |
| (a) Palepaleing. | | | | $3 to $4 per acre. |
| (b) Mulching. | | | | $3 to $3.50 per acre. |
| (c) Slitting. | | | | 30c to 40c per acre. |
| **Spraying** | | | | |
| (a) Knapsack. | | | | $6 to $8 per acre. |
| (b) Sled. | | | | $4 to $5 per acre. |
| (c) Hand pump with 3 hoses. | | | | $5 to $7 per acre. |
| **Making Rat Torpedoes** | | | 75c per 1000. | |
| **Dipping Rat Torpedoes** | | | 15c per 1000. | |
| **Trapping Rats** | | | $1 per day and 1¼c per tail extra. | |

Rates for such jobs as planting on irrigated and unirrgiated plantations necessarily vary a great deal. Hoeing in two adjoining fields on the same plantation, even where the amount and the size of the weeds are practically the same, may require very different prices, because one field may be very rocky and the other free from rocks, or the soil may naturally be very hard to work on one field and very easily handled on the other. These things must be kept in mind when studying the figures quoted. But an intelligent luna, using the figures as a base, can very easily see how much and where he must vary them to meet his own particular conditions.

When two or more rates are quoted for a job under an island heading, it is because the variation in the rate paid on the different plantations, due to conditions or to dissimilar work, require considerable differences in price.

### Sliding Scale Rates

An important improvement that has not been generally adopted for most short term contract jobs on the plantations is the use of the sliding scale in fixing rates. One plantation reports that it pays twelve cents a bag for throwing three or four bags of fertilizer per acre and gives a bonus of ten cents a bag for each bag over twelve that the laborer throws in a single day. This is a double incentive to the good men to work hard and earn more pay. Only the best men will profit by this arrangement, but it gives every man in the gang something to "shoot at."

This sliding scale rate is used quite generally in cutting and loading cane contracts. It can be used effectively for many more operations. Such practices really do not cost the plantations any more, because fewer men do more work and the lowering of the overhead will more than make up for the small amount extra paid to the good men as a bonus.

### Harvesting Rates

Harvesting rates are not discussed here because they are more or less fixed for the different islands and different conditions by the H. S. P. A. rulings. As a general rule, four to six cents per ton more is paid for cutting unburned cane than cane with all the trash on it. Such a variety as D 1135 costs about three cents a ton more to cut than the heavier Caledonia or H 109 canes.

As mentioned previously, it is now more or less common practice to use a sliding scale in paying for cutting and loading cane. This rate is usually a monthly proposition rather than a daily one so as to take care of the variation in the quality of the cane that the men must cut and load. There is quite a difference, due to the fields, stand and weight of the cane, variety, etc., in the amount a good man can do at different times. But for cutting or loading the minimum amount per month, the man is given the minimum wage. As the amount he does increases, the pay per ton automatically increases, so that the good man not only gets the extra pay for the extra work he accomplishes, but gets paid at a higher rate per ton for his services.

### Reporting the Work

Since the supervision and the setting of fair rates is such an important part of handling short term contract work, it is necessary to keep in close daily touch

with the amount of work done and the earnings per man. For this purpose some such form as the following is good for reporting work:

**THE MAIKAI SUGAR COMPANY**

Gang..... Field..... Operation.....

| Bango | Lines | Bags | Feet | Rate | Earnings | Remarks |
|---|---|---|---|---|---|---|
| | | | | | $ | |
| TOTAL | | | | | | |

Gang Luna.....

Section Luna.....

Date.....

This is merely a sample, and may be varied to suit the conditions or requirements of the various plantations. But any such jobs as hoeing, preparing lines, irrigating, spreading fertilizer, cutting seed, cleaning ditches or roads, etc., can be reported by simply filling in the proper heading under "Operation" and the amount done per individual man on the line with his bango number, marking under "Lines, Bags, Feet, Rate, etc.," the amount he has done and the rate he receives.

## Confidence Necessary

To get the best results with the men when giving short term contracts, it has been found that it is absolutely necessary to get and hold their confidence. Among the suggestions printed earlier in this paper is one that the rate suggested to the men be somewhat lower than the overseer really feels is the fair rate so that the men may have the satisfaction of "Jewing up" the price. The man who suggested this gave some of the most valuable suggestions printed in this paper, but seems to be wrong in this one particular. When one goes into a store to buy an article, he likes to have it offered at a reasonable price, and loses confidence in the store when the clerk begins lowering his price to make the sale.

When the men learn, after a few experiences, that the overseer is just as interested as they are in fixing a fair rate, they will soon take the price he gives them without complaint. They will know that if a mistake in judgment has been

made so that they can not make a reasonable wage with increased efforts, a fair adjustment will be made.

### Teach Your Men

A large majority of the men at present employed on our plantations are willing and anxious to do good work. Printed under "Suggestions for Improving Our Methods of Handling Short Term Contracts" is this statement by one overseer: "When commencing a new task, if men are shown what is wanted during the first hour, I have found that this is more than half the battle."

That is absolutely true. A good luna today is not the mythical old tyrant of the past, who "cussed and kicked" the work out of the men. He is the man who knows how to do the work well himself, and who can and does get in and *calmly* shows the men how the job is best done. A luna, with a hoe in is hand, going along the line covering up seed with long sliding scrape of his hoe on the upper edge of the furrow, can get his ideas across to the men ten times quicker and with a tenth of the effort of the man who simply stands and yells, "I told you to do it so-and-so way." Laborers respect intelligence in lunas. They appreciate friendly advice and help, but they resent unreasonable abuse from men who are either too lazy or too ignorant to *show* them how to do the job.

### Short Term Contracts For School Children

During the school vacations there are always a number of children around the plantations who want to work. It is good policy to give them employment, even when the plantation could probably get along without them. If we are to hold the younger generation on the plantations we are going to have to educate them along plantation lines, teach them to think of the plantation as their future homes, make the work fairly attractive to them, and show them that there really are good opportunities for them if they can "deliver the goods." The fixing of a day rate is often difficult for these children, because there is such a great difference in their abilities, regardless of their sizes.

The short term contract is also ideal for these young school boys. Every one gets paid for just what he does. They take a much greater interest in their work and they accomplish more. It is entirely reasonable to think that a far higher per cent of them will "stick to the plantation" than if their first impressions were gained from monotonous day work, where their idea is to watch the luna and the clock rather than to see how much they can earn by improving their work.

Times change. Improvements are constantly and universally being made in modern methods. Basing our plans upon the knowledge gained through years of experience in the past and upon scientific research in the present, we have to keep up with the procession or be lost. And it does not matter whether it is labor or machinery that we are handling. The principle applies just the same.

# Practical Sugar Cane Genetics*

By C. F. Poole

The object of the committee this year is to establish a common genetical basis for the solution of cane improvement problems, both in seedlings and bud selection.

## Sexual Improvement of Seedlings

With the development of the sulphurous acid solution by the Experiment Station, it is now possible to work with a greater degree of certainty in our seedling propagation. For the first time, now, we are able to use good control cross-pollination and self-pollination. Indian corn, or maize, is not only a close relative of sugar cane, but the two plants resemble each other in being normally cross-pollinated. It would be to our advantage, therefore, to adapt to our own uses some of the breeding experiments in corn, especially those concerned with hybrid vigor. This can be accomplished by producing near-homozygous strains, in inbreeding several generations of seedlings of the same two parents, or self-pollinating in one variety. After several generations of such work, possibly four or five, we should have a seedling or two, the seedlings of which, when self-pollinated, give individuals of uniformity of character, but greatly reduced vigor from the parent form (Castle, p. 242). The chief advantage of this consists in affording a ready means of eliminating all but the strongest individuals (Babcock, p. 356). After this point, cross-breeding will result not only in the combination of new parental characters, but the phenomenon of increased vigor over either parent.

On many plantations there are crosses of Lahaina and H 109, as well as Lahaina and other Lahaina seedlings, such as most of the seedlings of commercial promise at present on Kauai. The Experiment Station proposes to cross-pollinate among the D 1135—Uba seedlings.

## Factor Relations in Quantitative Inheritance

The main object in analyzing factor relations is to learn the manner of inheritance. This is a line of investigation that has not yet been applied in Hawaii. It would be of great value in seedling propagation to have definite information along these lines, and it might be well to consider the subject under the following heads:

1. Do any characters exhibit typical Mendelian inheritance, that is, after the second generations are the parental characters segregated in the ratio of 3-1?

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

2. In the first generation of a hybrid are the characters of each parent blended to form intermediate characters?

3. Are some factors linked together in the first generation while others disappear and reappear in subsequent generations?

To answer such questions we must have, first, definite knowledge of the two parents, and, second, sufficient offspring from such a cross to provide a fair measure of the range of inheritance for any particular factor.

In the accompanying table is submitted a list of twenty-five seedlings which are presumed to be natural field hybrids, with the female parent and the probable male parent indicated, showing the size of each seedling for the specific factors considered. For convenience in study, they are presented in groups of five seedlings, each group consisting of those of the same probable parents. At the end of each group the same data are presented for the two parents.

The short space of time available for the preparation of this section of the paper has made it impossible to include a large enough number of seedlings per group to furnish a fair range for any of the factors. However, those included will serve the purposes of a preliminary study and afford an opportunity for suggestion and criticism.

Measurements for the parent varieties, D 1135 and H 109, were made in the same field as the seedlings, but the Lahaina was obtained elsewhere, and in a location where the so-called "Lahaina trouble" was evident. The particular stool measured, however, seemed to have recovered a normal growth. These three parent varieties consisted of one stool each, issuing from a single-eye seed piece, whereas the seedlings were from the first field test, and, therefore, not from vegetative cuttings. This renders invalid a comparison of the number of stalks between parents and offspring.

Examining the available material, it is evident that few, if any, conclusions are warranted. However, it is interesting to note, from a comparison of the group averages:

1. There is apparently no loss in vigor in the case of self-pollination, or cross-pollination between two closely related varieties like Lahaina and H 109, such as would be expected in inbreeding.

2. It appears that H 109 as a female parent in the vicinity of the D 1135 to the windward furnishes poor seedlings.

## Size Inheritance

| Seedling | Circum. | Length Joint | Area of Nodes in Inches | Aver. 30 Days Growth in Inches | Leaf Ratio | No. of Stalks | Parentage (Female First) |
|---|---|---|---|---|---|---|---|
| A 11.7 | 4.55 | 4.05 | 18.43 | 8.8 | 19.1 | 16 | |
| A 24.7 | 5.46 | 3.00 | 16.39 | 7.9 | 20.5 | 4 | |
| A 25.7 | 4.14 | 3.82 | 15.81 | 9.0 | 19.4 | 16 | D 1135 x H 109 |
| C 6.1 | 3.59 | 2.74 | 9.83 | 6.8 | 22.3 | 12 | |
| B 25.5 | 5.21 | 3.56 | 18.57 | 9.6 | 21.2 | 18 | |
| Average | | | 15.81 | 8.4 | 20.50 | 13.2 | |
| D 1135 | 3.63 | 3.25 | 11.80 | 6.9 | 21.4 | 7 | |
| H 109 | 4.95 | 3.68 | 18.22 | 7.5 | 18.9 | 5 | |
| Average | | | 15.01 | 7.2 | 20.15 | 6 | |
| C 15.5 | 4.77 | 3.53 | 16.82 | 12.6 | 19.2 | 13 | |
| C 20.1 | 4.47 | 3.86 | 17.27 | 9.0 | 17.6 | 16 | |
| C 21.8 | 4.51 | 3.75 | 16.91 | 9.4 | 20.0 | 14 | H 109 x Lahaina |
| D 3.9 | 4.45 | 3.33 | 14.82 | 9.0 | 21.0 | 14 | |
| D 26.8 | 4.23 | 3.71 | 15.70 | 9.8 | 21.1 | 15 | |
| Average | | | 16.30 | 9.96 | 19.77 | 14.4 | |
| H 109 | 4.95 | 3.68 | 18.22 | 7.5 | 18.9 | 5 | |
| Lah. | 4.28 | 2.57 | 11.00 | 6.9 | 24.6 | 5 | |
| Average | | | 14.61 | 7.2 | 21.75 | 5 | |
| B 20.7 | 4.44 | 3.56 | 15.80 | 9.0 | 22.2 | 11 | Lah. x ? (Big Ribbon on windward; no tassels at time of collection.) |
| B 21.2 | 5.32 | 3.53 | 18.78 | 8.9 | 18.5 | 12 | |
| B 24.5 | 5.99 | 3.33 | 19.97 | 6.6 | 18.8 | 6 | |
| C 32.2 | 4.54 | 3.47 | 15.77 | 8.3 | 19.0 | 14 | |
| B 23.1 | 4.19 | 4.18 | 17.52 | 10.8 | 21.1 | 11 | |
| Average | | | 17.57 | 8.72 | 19.92 | 10.8 | |
| Lah. | 4.28 | 2.57 | 11.00 | 6.9 | 24.6 | 5 | |
| C 12.1 | 4.85 | 3.11 | 15.09 | 8.0 | 22.4 | 9 | |
| D 24.8 | 4.97 | 3.74 | 18.59 | 9.0 | 16.5 | 12 | |
| D 25.5 | 5.94 | 3.25 | 19.30 | 9.0 | 21.7 | 12 | Lah. x H 109 |
| D 30.8 | 4.31 | 3.03 | 13.07 | 7.2 | 22.0 | 19 | |
| C 13.7 | 4.62 | 3.13 | 14.48 | 7.6 | 20.0 | 9 | |
| Average | | | 16.11 | 8.16 | 20.52 | 12.2 | |
| Lah. | 4.28 | 2.57 | 11.00 | 6.9 | 24.6 | 5 | |
| H 109 | 4.95 | 3.68 | 18.22 | 7.5 | 18.9 | 5 | |
| Average | | | 14.61 | 7.2 | 21.75 | 5 | |
| A 22.1 | 4.14 | 2.62 | 10.86 | 5.5 | 19.4 | 26 | |
| A 13.1 | 3.46 | 3.70 | 12.80 | 7.1 | 21.7 | 23 | |
| A 13.2 | 4.31 | 3.39 | 14.62 | 8.0 | 20.2 | 10 | H 109 x D 1135 |
| B 19.2 | 4.40 | 1.85 | 8.14 | 5.0 | 17.3 | 6 | |
| D 2.2 | 2.94 | 2.79 | 8.21 | 6.9 | 17.5 | 12 | |
| Average | | | 10.93 | 6.5 | 19.22 | 15.4 | |
| H 109 | 4.95 | 3.68 | 18.22 | 7.5 | 18.9 | 5 | |
| D 1135 | 3.63 | 3.25 | 11.80 | 6.9 | 21.4 | 7 | |
| Average | | | 15.01 | 7.2 | 20.15 | 6 | |

3. From the leaf ratio of the first group seedlings, it might be concluded that the narrower D 1135 leaf is transmitted to the majority of the seedlings. This likewise might be the case in the fourth group, where Lahaina is the maternal parent.

4. Providing cross-pollination, as indicated for each group, has been effected, it seems more probable that a blended type of inheritance is transmitted, although it must be admitted that five seedlings per group are insufficient for such an assumption.

One point that is made clear from this exercise is that all our parent and seedling varieties are too heterozygous to furnish definite information along these lines. It is hoped that this line of investigation will be followed up in the near future, and that homozygous canes will be bred and used for the purpose. According to Jennings and Fish, as quoted by Castle, homozygosity is approached by inbreeding three times as rapidly by self-fertilizing as by mating brothers and sisters. It is also possible to obtain homozygosity immediately, or never.

## A Sexual Improvement, Mutations, Bud Selection, Etc.

(a) *Mutations:* It is well known that sugar cane is subject to mutations. These mutations may be the result of a recombination of ancestral characters in the body cells of hybridized varieties, or they may be factor mutations, new combinations in the germ cells. At any rate, we know they are heritable, and have given rise to some of our most important varieties of cane, as, for instance, Yellow Caledonia.

In the following table are shown the color mutations that have arisen within only three generations in a single stool of three stalks of Big Ribbon. In 1924, there were three stools, two of which remained Big Ribbon, and were not spread further, the other stool giving rise to a mutating stalk, consisting of six stalks of Big Ribbon and one stalk which started as Big Ribbon and changed to Black Tanna. Three seeds of each kind were taken from this one stalk. At the same time as Black Tanna was forming in this one stalk, there seemed to be a tendency in a few of the other stalks to lose their stripes. And in the following generation five of those stools gave rise to one stalk each of Yellow Caledonia. (B. R. is Big Ribbon, B. T. is Black Tanna, Y. C. is Yellow Caledonia, and M. is mixed joints on one stalk):

| | 1925 | | | | 1924 | | | | 1923 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B. R. | B. T. | Y. C. | M. | B. R. | B. T. | Y. C. | M. | B. R. | B. T. | Y. C. | M. |
| (a) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | | | | |
| (b) | 0 | 2 | 0 | 0 | (Black Tanna) | | | | | | | |
| (c) | 0 | 1 | 0 | 0 | | | | | | | | |
| (d) | 1 | 1 | 0 | 0 | | | | | | | | |
| (e) | 0 | 3 | 0 | 0 | (Big Ribbon) | | | | | | | |
| (f) | 0 | 3 | 0 | 0 | | | | | 3 | 0 | 0 | 0 |
| (g) | 3 | 0 | 1 | 0 | | | | | | | | |
| (h) | 1 | 0 | 1 | 0 | | | | | | | | |
| (i) | 1 | 0 | 1 | 1 | | | | | | | | |
| (j) | 2 | 0 | 1 | 0 | | | | | | | | |
| (k) | 2 | 0 | 1 | 0 | | | | | | | | |
| (l) | 2 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | | | | |
| (m) | 3 | 0 | 0 | 0 | | | | | | | | |
| (n) | 3 | 0 | 0 | 0 | | | | | | | | |
| (o) | 1 | 0 | 0 | 0 | | | | | | | | |
| (p) | 5 | 0 | 0 | 0 | | | | | | | | |
| (q) | 5 | 0 | 0 | 1 | | | | | | | | |
| | | Not Spread | | | 8 | 0 | 0 | 0 | | | | |
| | | " " | | | 9 | 0 | 0 | 0 | | | | |

Several other pedigrees of a like nature in Big Ribbon suggest that once a stalk of Black Tanna or Yellow Caledonia has been formed, there is a strong tendency, which has not yet been observed to fail, to maintain the new mutation.

(b) *Pure Lines:* Twenty-five progenies of H 109 cane have been under observation for three generations. In 1923 (the second year), these twenty-five progenies were divided into two sections, Section 4 containing all stools of five or more stalks, and Section 5 the smallest stools remaining. In 1924, a second selection was made within these two sections on the basis of the sub-progeny performance, in which only one-quarter of the sub-progenies were selected. This gives us different mean values for: (X) the average of the sub-progenies constituting the main progeny, (A) the average of only those sub-progenies qualifying for planting in the 1924 project, conforming again to the idea of selecting plus variants, but making discards of entire sub-progenies and not individual stools.

As will be seen from the following table, material improvement resulted from this second selection in the: (1) mean stalk-stool coefficient, M, (2) standard deviation, $\sigma$, and (3) coefficient of variability, C$\sqrt{}$.

| | 1922 | | | 1923 | | | 1924 | | |
|---|---|---|---|---|---|---|---|---|---|
| | M | $\sigma$ | C$\sqrt{}$ | M | $\sigma$ | C$\sqrt{}$ | M | $\sigma$ | C$\sqrt{}$ |
| Sec. 4 | 4.364 | .213 | 4.87 | X—5.06 | .168 | 3.32 | 4.88 | .492 | 10.07 |
| | | | | A—5.53 | .148 | 2.68 | | | |
| | | | | Sub—5.56 | .332 | 5.96 | 4.80 | .637 | 13.26 |
| Sec. 5 | 4.365 | .284 | 6.49 | X—5.33 | .310 | 5.82 | 4.55 | .628 | 13.75 |
| | | | | A—6.12 | .230 | 3.76 | | | |
| | | | | Sub.—6.16 | .413 | 6.70 | 4.66 | .717 | 15.39 |

In each generation, both 1923 and 1924, there has been a failure of the selection of plus variants to improve the population. In fact, in 1923, it appears that

Section 5 is superior to Section 4, giving a negative effect for plus selection; however, in 1924, the relative yields of the two sections are again reversed. The line "Sub-" refers to data obtained studying the correlation among the sub-progenies, while X and A refer to the average of whole progenies.

The coefficients of correlation between the S-S coefficients for the three generations here recorded are quite erratic. For 1922-1923, they are $0.2779 \mp .1671$ for Section 4, and $0.3138 \pm .1285$ for Section 5. Subsequent correlations are inconsistent, due, no doubt, to the small number of progenies per section. However, they do not affect the parallel behavior between this vegetatively propagated material and Johannsen studies in "pure lines."

This is more strikingly brought out by tabulating the values of these two sections according to ranks, as determined by the stalk-stool coefficient.

After three generations these twenty-five progenies had been condensed by selection to fourteen progenies in Section 4, and twenty-three progenies in Section 5, and the fourteen progenies of Section 4 were brother progenies to fourteen of the Section 5 progenies. In Sections 4 and 5 there were two progenies each which showed superior performance for all three generations, and, very significantly, the two progenies of Section 4 were the brother progenies to the two progenies of Section 5, Nos. 33 and 38. Also, it appears that Nos. 9 and 20 have been consistently poor.

In the following table, the progenies will be designated by the original field number of 1922. The numbers of the table under the three main columns, 1922, 1923 and 1924, show the ranks, and the fourth column shows the numerical total of the ranks:

RANK BY STALKS-STOOL COEFFICIENT

| | Section 5 | | | | Section 4 | | | |
|---|---|---|---|---|---|---|---|---|
| No. | 1922 | 1923 | 1924 | | | | | |
| 1 | 1 | 11 | 20 | 32 | | | | |
| 2 | 2 | 12 | 22 | 36 | | | | |
| 3 | 15 | 18 | 21 | 54 | | | | |
| 5 | 16 | 6 | 13 | 35 | | | | |
| 7 | 12 | 9 | 15 | 36 | | | | |
| 9 | 22 | 13 | 23 | 58 | | | | |
| 12 | 7 | 16 | 17 | 40 | | | | |
| 15 | 17 | 1 | 14 | 32 | 1922 | 1923 | 1924 | |
| 18 | 23 | 4 | 12 | 39 | | | | |
| 20 | 18 | 32 | 19 | 59 | 11 | 13 | 10 | 34 |
| 22 | 13 | 20 | 16 | 49 | 9 | 8 | 4 | 21 |
| 26 | 4 | 23 | 2 | 29 | 2 | 14 | 6 | 22 |
| 27 | 19 | 8 | 7 | 34 | 12 | 9 | 2 | 23 |
| 29 | 20 | 14 | 10 | 44 | 13 | 10 | 7 | 30 |
| 33 | 6 | 3 | 5 | 14 | 4 | 1 | 1 | 6 |
| 35 | 11 | 2 | 11 | 24 | 8 | 4 | 8 | 20 |
| 36 | 21 | 5 | 4 | 30 | 14 | 6 | 5 | 25 |
| 37 | 8 | 21 | 3 | 32 | 5 | 12 | 12 | 29 |
| 38 | 3 | 7 | 1 | 11 | 1 | 2 | 3 | 6 |
| 42 | 5 | 15 | 6 | 26 | 3 | 3 | 14 | 20 |
| 45 | 10 | 10 | 18 | 38 | 7 | 11 | 9 | 27 |
| 47 | 9 | 19 | 8 | 36 | 6 | 5 | 11 | 22 |
| 49 | 14 | 17 | 9 | 40 | 10 | 7 | 13 | 30 |

Theoretically, a new seedling, such as H 109, behaves like a "pure line" when it is propagated by vegetative cuttings. However, a mutation within this seedling would establish another pure line, and if the seedling is given to many mutations, we should, in a short time, have a mixed population. In view of the above results, and of the further fact that H 109 throws color mutations, which are very evident, we may safely assume that we have such a mixed population in these two sections of H 109.

Using Babcock as an authority: "There is now abundant evidence that genetic diversity is expressed in minute morphological and physiological differences, and hence that mutations produce those small inheritable differences logically required for the explanation of adaptation through natural selection."

(c) *Bud Selection:* It is now about five years since the problem of bud selection was first applied to sugar cane in Hawaii, and from the number of projects now in process there should be ample mathematical evidence of its success or failure. However, in the absence of any such data being published, it is the purpose of the committee to present some figures, and outline a few standard biometrical methods of study. It is also our hope to establish a common basis of handling selection problems on the individual plantations.

In analyzing the situation up to the present, there are certain fundamental questions that must be considered: first, are we making any progress? second, what methods of selection are most adequate?

In dealing with the first question of progress, it is important that we use standard methods applicable to the particular work being done. Are we using a method of mass selection, or is it a pedigree system? In mass selection, we take a population of which we know the average yield and attempt to improve this average by eliminating poor material. This is almost sure to effect a favorable result, for the evidence disclosed by pure line investigation, and our knowledge of poor mutations, shows that some inherently inferior individuals can be recognized at sight. But we cannot distinguish superior mutations from the heavier type of chance variations that depend on environment, and what improvement is made is sure to be small and to require a long period of time. On the other hand, with pedigree culture we segregate the individual progenies and keep careful and complete record of the performances of it and of its sub-progenies for several generations. This enables us to know the comparative quality of each progeny. It would be fatal to the system if any eliminations were made of stalks, stools, or sub-progenies.

By the latter method we can distinguish a superior yielding progeny in a comparatively short time, whereas in the former method we must always keep a mixed population in which all the mediocre material can never be identified and discarded.

From evidence thus far available it appears that variability in yield is more evident than constancy. Only a small percentage of the progenies in the upper distribution will remain constant for two successive years, and a smaller percentage still for three successive years.

The only effective method of measuring the strength of relationship between the progeny performances from year to year is the coefficient of correlation. In no other way can we tell if there are any constant mutations.

In the following table, the correlation coefficients for eight sections of cane, comprising the three standard varieties, together with the probable errors, are given. Recently, some of these coefficients have been rechecked, and although some errors were found, the results are substantially as here recorded; as time is short, a recalculation is immaterial. The standard of measure applied to each progeny, called, for short, the stalk-stool coefficient, is obtained by use of the following formula: 6.67 log $\sqrt{\quad}$ a b, in which $a$ is the stalks per foot, and $b$ is the stalks per stool. Use of the formula is simplified with a chart having logarithmic scales to represent $a$ and $b$ parallel to each other and 8 inches apart, while the coefficient is read on an inch scale parallel to and two-thirds the distance from $a$ and one-third the distance from $b$, as illustrated in the annual report on bud selection for 1924. By correlating the stalk-stool coefficients for two successive years, the coefficient of correlation is obtained.

| Section | Variety | N | r | e | $\frac{1}{e^2}$ | $\frac{r}{e^2}$ |
|---|---|---|---|---|---|---|
| I | H109 | 104 | —0.0286 | 0.0661 | | |
| II | H109 | 79 | 0.5405 | 0.0538 | | |
| III | D1135 | 91 | 0.2881 | 0.0648 | | |
| V | Cal | 32 | 0.4055 | 0.0994 | | |
| VI | H109 | 39 | 0.1487 | 0.1053 | | |
| VII | H109 | 107 | 0.4035 | 0.0546 | | |
| VIII | Cal | 110 | 0.2831 | 0.0596 | | |
| X | H109 | 53 | —0.0805 | 0.0921 | | |
| | | 615 | +0.2926 | ±0.024 | 1738.86 | 508.84 |

Leaving out the minus correlations we have:

| | | | |
|---|---|---|---|
| +0.3770 | ±0.0268 | 1392.08 | 524.88 |

From this table it is readily seen that five out of eight of these sections show a pronounced correlation, while two of these sections have slight minus correlations, an abnormal, though sometimes found case. Therefore, if we omit these two latter sections, particularly in view of the fact that their consecutive environments are very extreme (an unfair test), we have a correlation coefficient for six sections, comprising 458 progenies, of 0.3770 ± 0.0268. In order to establish the presence of correlation, the original coefficient of 0.2926 ∓ 0.0240 is amply sufficient, and leaves no room for doubt.

Coming, now, to the second question, that of reliable and adequate methods of selection, nothing is to be gained by eliminations either of poor stools or poor progenies until we reach a stage where we have a definite identification of superior and inferior progenies, which I should say is at least three generations. In the language of pure lines, these two classes of progenies would constitute progressing and regressing mutations, respectively.

As for the methods themselves, it is desirable to have a criterion of identification that measures both the heredity, and as much as possible of the environment. In theory, at least, these two requirements are partially satisfied by use of the stalk-stool formula referred to above, modified as follows: 6.67 log $\sqrt{\phantom{x}}$ a b plus 1/X times mortality %, multiplied by the circumference of stalks, in which x is the coefficient of regression of mortality, obtained as the final step in *multiple correlation.*

The use of weights as a measure of quality or selection, would be very satisfactory providing we had (1) a uniform environment, (2) perfect germination, and (3) a sufficient area of each progeny to minimize errors. However, these three conditions are impossible to satisfy in the early stages, so long as we are using (a) single-eye seed, which is necessary for pedigree cultures, (b) planting in soils like the majority of our Hawaiian soils that vary in quality over very short distances of ground, and (c) have to make our selection hastily from large numbers of progenies.

Discussing the merits and demerits of this method of measurement, it would be well to go into detail. Stalks per foot, stalks per stool, and circumference of stalks, are measures of volume, and certainly weight of cane is a heritable factor, as already proved by correlation. For some time past, it has been thought that the percentage of shoots dying between the time of germination and stalk development has been correlated with the yield.

The percentage of mortality was assumed to be similar to a percentage that would be obtained by dividing the difference between the stalk-stool coefficients for October and January by the stalk-stool coefficients for October. This gives us an algebraic mortality percentage, and for the 615 progenies mentioned above, the correlation coefficient for 1924 is $0.6285 \mp 0.0168$.

The next step was to find if any correlation existed between the algebraic mortality percentages for the two consecutive years. The correlation coefficient in this case was found to be practically zero.

It was then assumed that percentage of mortality furnished an index of environment. We may, therefore, measure and eliminate this influence and have a better idea of the quality of the progenies. Accordingly, multiple correlation as used by Yule in *An Introduction to the Theory of Statistics* was employed, using the four factors: $X_1$ S-S coef. for 1923; $X_2$ S-S coef. for 1924; $X_3$ mortality percentage for 1923; and $X_4$ mortality percentage for 1924. By this method we obtain the regression coefficients for each of these four factors, and that for $X_4$ shows the influence exerted on $X_2$, as in the following example. In a section of 110 progenies of Yellow Caledonia we obtain the formula:

$$X_2 = 1.703 + 0.770x_1 - 0.003x_3 - 0.035x_4$$

In this section the significant figure is $-0.035x_4$, but for five sections it is $-0.047$. This, then, means that if the S-S coef. of 1924 is increased by .05 (or 1/20) we have our desired correction.

Therefore, we are using the new formula: y+X4/20, in which y is the old S-S coef. and X4 is the mortality percentage for the same year. The test of

this formula, which has only recently been developed, lies in the improvement that will be made in simple correlation.

Up to the present time, improvement has been obtained in three cases, and losses in two cases.

The chief limitation of this method of measuring pedigree cultures lies in the absolute necessity for accuracy in field measurements.

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# The Adaptation of Hawaiian Seedlings*

By Y. Kutsunai

In a general way, the districts and plantations to which our seedlings are adapted are those with environments similar to the growing conditions under which the parent canes used in our seedling work thrive.

The present sugar cane belt can be roughly divided into four zones. The lowest zone, which has the warmest climate, is planted with H 109. There are indications that seedlings of Lahaina and H 109 are particularly suitable for this division. This may be called the H 109 zone, for convenience.

The next is a little cooler than the H 109, and may be termed the Yellow Caledonia zone from the predominating variety here grown. The seedlings of Yellow Caledonia are being raised with the intention of supplying better varieties to take the place of the parent.

The D 1135 zone follows the Yellow Caledonia. A large number of seedlings of D 1135 have been raised, but none has yet been found to compete successfully with the parent. The failure is perhaps due to the fact that D 1135 has a strong tendency to self-fertilization and produces rather weak seedlings as the result of inbreeding.

The highest, and consequently the coolest, portion of the sugar cane belt may be termed the Tip zone. Formerly this zone was thought to be the most difficult one to supply with seedlings. However, in 1917, Tip canes, and, in 1923, Uba cane, were introduced into the seedling work with the result that many promising varieties for this coolest area have sprung up.

Thus far, sugar cane breeding and the subsequent selection of seedlings has been confined to the established sugar cane belt. If the present sugar cane boundary is to be moved beyond the upper limits of the Tip zone, it will become necessary to carry the seedling work to this new area. It may be advisable to import from foreign countries new hardy varieties of cane to be used as parents, since among our present varieties, D 117, Badila, H 146, H 227, H 456, H 468, Striped Mexican, native varieties, and new Hawaiian seedlings, none seem to be suited as parents for canes to be grown at very high elevations.

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In addition to the prevailing average annual temperature, as above referred to, there are many other factors affecting the adaptability of Hawaiian seedlings. Among these factors may be mentioned rainfall, wind, type of soil, diseases of sugar cane, insect enemies, rats, weeds, mill equipment, amount of irrigation water, agricultural practice, prejudice, etc.

### Rainfall

Many seedlings that have appeared promising under irrigated conditions cannot be successfully handled in a rainy region of equal temperature. The effect of heavy rainfall on non-stripping seedlings and lodging seedlings is obviously detrimental, and rain also seems to induce differences in soil and humidity of air. Yellow Caledonia is almost an ideal cane in the rainy district. It is erect, self-stripping, and eye spot resistant. Its seedlings are naturally looked upon with much interest for the Hilo coast.

### Wind

This Territory is seldom visited by strong winds, which, consequently, are not generally considered as a factor affecting the adaptability of Hawaiian seedlings. Honokaa No. 1 is the first to be reported as a good cane in windy places, because it seems to be less torn by strong winds than any other variety.

### Soils

There are many types of soil ranging from the neutral soil of the coastal plains to the acid soil of the higher rainy belt. Some are wanting in phosphoric acid, and others are in need of potash. However, varied as they are, the soils have not so far been considered very much as factors to be reckoned with in seedling distribution. Although they have important bearings on varietal adaptability, they are usually considered in the question of fertilizers.

### Diseases

Such diseases as root rot, eye spot, and mosaic have rightly played an important part in deciding seedling distribution. In the case of root rot, a Hawaiian-grown seedling, H 109, has not only solved the problem but also increased the sugar yields, so that the variety is now planted irrespective of this disease. The eye spot situation is being worked out with such seedlings as H 5965 and H 8965. Mosaic disease, which hits the Tip canes very severely, is being met with Tip seedlings and Uba crosses, particularly U. D. 1.

### Insects and Rodents

The control of damage due to insects and rodents through seedling work has not progressed far enough for discussion.

### Weeds

Weeds, especially in the wet districts, have been a matter of great importance in the minds of cane breeders. Although no seedling has been evolved as yet to meet weedy conditions, it is hoped a variety may be found which will grow rapidly enough to shade in the weeds, thus cutting down on cultivation expenses.

### Milling Quality

A certain type of seedling, although fair in sugar producing power, cannot be satisfactorily handled at the mill because of the pulpy nature of its bagasse. As an example we have H 468.

### Irrigation Water

The amount of available irrigation water often influences the adaptation of our seedlings. H 5001 and XY are reported doing well on plantations which feel the shortage of irrigation water. U. D. 58 has grown to respectable size on dry spots where H 109 had previously failed for lack of water.

### Agricultural Practice

Agricultural practice, particularly the amount of fertilizer applied, affects the adaptability of seedlings. For instance, under very low fertilization D 1135 outyields H 109, but when an adequate amount is used, H 109 not only outyields but gives greater profit than D 1135.

### Prejudice

Prejudice sometimes handicaps a good seedling. A head overseer once remarked that he would not plant D 1135 any more because his harvesting force would not handle a crop of that variety. Although labor is an important item to consider, such an attitude is not in accord with progressive management.

Theoretically speaking, Hawaiian seedlings will eventually cover every district, field, knoll, and valley of our cane belt. There is a difference in the attitude of the cane breeder of the past and the present day in reaching this goal.

The older cane breeder produced seedlings without accurate knowledge of hereditary characters of the parental varieties. Since only a small proportion of the total number of seedlings grown in a year could be thoroughly tested on each plantation, the odds were all against a variety finding the environment to which it was especially adapted.

The present day cane breeder starts with a district, a plantation, or a locality which has a set of given conditions, and he tries to produce seedlings to suit the objective area. It is necessary in this case to study the hereditary characters of the breeding stock so as to impart to the seedlings the characters that are essential for successful growth under the given conditions.

In a study of the inheritance characters of sugar cane varieties, it seems to be important to recognize that some of the dominant and some of the recessive characters of a parental variety are transmitted in dominant form in the immediate seedlings, while some of the characters which remain recessive in the parent and the immediate seedlings, become dominant in the later seedlings. D 1135 gives occasional seedlings without eyes. H 20, a seedling of D 1135, sometimes stops developing eyes. Out of 350 seedlings of H 20, about 120 did not develop eyes on the upper parts of the sticks. Another case is seen in the seedlings of H 456 which is a seedling of H 240. Among about 2000 seedlings of this, nearly 33 per cent grew with bound-up leaves. Queer characters such as these are rare among the standard varieties, but they occasionally come to light through seedlings.

The standard varieties of today appear to be canes with good dominant characters. They, however, may possess undesirable characters that are now recessive.

Characters that are usually transmitted by the parental canes follow:

| *Parent* | *Characters Usually Transmitted* |
|---|---|
| D 1135 | Slow growth, occasional eyelessness, poor juice, adaptability to cool climate, small sticks, good ratooning power. |
| Lahaina | High sucrose content, poor ratooning quality, adaptability to warm field, large sticks. |
| H 109 | Rapid growth, high sucrose content, adaptability to warm locality. |
| Tip canes | Adaptability to cool climate, small size stick, good ratooning power, poor juice. |
| Uba | Small sticks, adaptability to cold climate, poor juice, long joints, good ratooning power, rapid growth. |
| Striped Mexican | Large sticks, fair juice, poor ratooning quality, rapid growth, medium length joints. |
| Badila | Slow growth, high sucrose content, soft tissue, large sticks, short joints. |
| Y. C. | Large sticks, medium length joints, good growth, other characters are unknown as yet. |

This list is based on impressions and is very far from complete. It is meant to be a beginning in the study of sugar cane heredity.

Inbreeding has been resorted to for the purpose of obtaining very accurate data on the hereditable characters of standard varieties generally used in seedling work here. To date, most of the selfed seedlings that have been obtained are weak and cannot stand the field conditions. Interesting examples of this nature are Badila and Lahaina selfs. Badila selfs resemble the parent variety very much except in their weak growth. These have since all died out. A Lahaina self was obtained by an early worker, but it also died. D 1135 and H 109 produce inbred seedlings. Although they survive the field conditions, they are usually weak growers.

H 1801 is one of the exceptions to this generalization. Its selfed seedlings appear to be just as vigorous as the parent.

In spite of this defect, inbreeding is perhaps the most accurate method for studying heredity, and it is hoped that in time this procedure will not only accumulate sufficient data, but will also obtain true-breeding seedlings with economic characters. Through these it may become possible to create by judicious crossing a super cane with high sugar-yielding power, high degree of disease resistance, good adaptability to given conditions, and low cost of production.

In conclusion it should be stated that seedling work is still in its infancy and needs the assistance of everybody concerned.

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# Fire Protection for Sugar Mills*

By Bernard Froiseth

For a great many years the fire insurance companies did not consider that it would be better business to encourage the assured to improve their property from a fire insurance standpoint, believing that their business was merely to collect premiums and distribute losses. However, the companies in recent years have changed their attitude in this regard and now encourage the assured to practice fire prevention and protection, and they maintain many organizations which make fire prevention inspections.

Sugar mills should be safeguarded in every possible way against loss by fire, and the insurance companies recognize effective protection afforded a plant by substantial credits in the rate of insurance.

Attention is called to the fact that a sugar mill may be fully covered by insurance at the time of a fire, but that the owners might suffer severe consequential losses over and above the amount of insurance that they might collect. Such uninsured losses might occur from interruption of business and also from their inability to grind the crop of growing cane.

The principal fire hazards of a sugar mill are in the boiler room, electrical installation, and steam pipes, and these hazards shall be commented on briefly before going into the matter of fire protection and prevention.

## Boiler Rooms

The hazards of boiler installation come chiefly from explosion, from overheating of chimneys or stacks, with consequent setting fire to buildings; from ignition of floors, partitions, or other woodwork near by, and in connection with fuels such as oil, coal, wood, bagasse and sweepings.

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The greatest safety for any boiler installation is secured with a detached building, preferably incombustible. When it adjoins a sugar mill or warehouse, the boiler room should preferably be of fire-resistive construction, cut off with standard fire doors. If boilers are located in the mill building, the floor construction over them should be incombustible, there should be ample clearance, and neither combustible finish floor nor combustible storage kept immediately over the boiler room, if there is the least possibility of transmitted heat producing a dangerous temperature. Concrete or tile construction holds and transmits long-continued heat to a dangerous degree.

Roughly speaking, any boiler or heating device so installed that it heats surrounding wood or other inflammable material to a temperature of 150° F., or slightly more, and for a considerable period of time, is likely to cause a fire. It is astonishing to observe under what apparently safe conditions it is possible for long continued low temperatures to cause a fire.

The hazard from bagasse in the boiler room cannot be overestimated. The recent fire in the mill of the Oahu Sugar Company clearly demonstrated the fact that bagasse is subject to spontaneous combustion. The bagasse and cane dust which settle on frame, walls and roof of sections of a mill building are very combustible and constitute a menace to a plant if it is allowed to accumulate.

## Electrical Fire Causes

The fundamental causes of electrical fires are arcs and overheating. The separation of conductors or parts of different potential and the design of equipment to carry safely ordinary loads and even overloads, coupled with automatic protection (fuses or circuit breakers) to open circuits if overloads become severe enough to become dangerous, enter into the design of all electrical equipment. This should be actively borne in mind in considering electrical fire hazards.

Generators have substantially the same fire hazards as motors. Disastrous fires have occurred because crane blocks have come in contact with generator connections.

Switchboards of the modern type contain little fire hazard.

Switches are dangerous largely because of poor contacts and connections causing arcs or heating, and because, if exposed and struck by metal, violent short circuits may result.

Oil switches have proved to be a very definite fire cause. The hazard lies chiefly in the oil switch rupturing under heavy overload, as from short circuits on lines, burning oil being scattered and fire spread thereby. Not only have incombustible buildings been destroyed by such fires, but the life hazard has also proved to be a considerable one.

Transformers containing oil for insulating and cooling purposes have caused some exceedingly severe fires in industrial plants.

Fuses and circuit breakers are the safety valves of electrical systems. They are often omitted and frequently abused. Circuit breakers are commonly set unnecessarily high. Fuses are too large, cartridge fuses are refilled or bridged with fuse wire of too high carrying capacity, and occasionally copper wire will

be found in place of fuses. For reasons of safety, economy and convenience, cartridge fuses properly designed should be used generally.

Temporary wiring, even if admitted dangerous in the first place, very frequently becomes permanent. Even temporary wiring should be safely installed and all dead wiring promptly removed so that it will not be connected up after disuse has permitted deterioration.

### "Flash Fires"

On the mainland they have had numerous "flash fires" in sugar warehouses, caused by fibrous matter from sugar bags spreading itself on the floor—fire being occasioned by friction from the iron wheels of trucks and also from nails in the shoes of workmen. This hazard is much greater where floor is concrete than on a wood floor.

### Fire Prevention

Fire prevention is fire protection. Fire prevention is a very important matter, and the old adage might be changed to read "An ounce of fire prevention is worth more than several hose streams." It is easier to guard against a fire than to extinguish it after it has once been started. Good housekeeping should be emphasized; also careful guarding of hazardous operations. If fires can be prevented from being started, naturally the fire extinguishing equipment will not be called upon.

### Fire Protection

It must be borne in mind that private fire protection at the best is first aid only. A private fire department cannot be expected to cope with a serious fire; for that reason all equipment must be kept in first-class condition in order to extinguish a fire at the beginning or prevent its spreading. The protection system should be inspected regularly, beginning at the water supply and following through the supply mains, hydrants and hose, making certain that everything is as it should be. All equipment should be examined and tested. Inside protection should be carefully gone over, not only to see that it is in perfect working condition, but it should be readily accessible and distributed according to the type that is most effective for extinguishing the kind of fire that may occur.

### Outside Fire Protection

Next in importance to an adequate water supply is an adequate distributing system. Such a system should be able:

1st: To deliver the desired amount of water at all important points without serious pipe friction. Keeping within a 25-pound friction allowance is good practice.

2nd: To permit concentrating all available water at important points with hose lines not over 150 feet long. This usually calls for a fairly complete covering of the plant with the piping system.

It is vitally important that absolute separation be secured as far as fire and domestic piping is concerned, for the following reasons:

(A) Domestic piping is frequently not so heavy or so well installed as fire mains, with subsequent breaks or blowouts when fire pressure is applied.

(B) Domestic connections in buildings may be broken by fire and the system bled. Safely located control valves are seldom installed in combined systems. Also, the amount of high pressure water available is limited, as a rule.

(C) Changes in domestic piping may interrupt fire service frequently in the course of a year.

A liberal number of hydrants makes for economy and efficiency. A hydrant costs only two to three times as much as a length of hose, and the depreciation on hydrants is far less than on hose. Friction in long lines of hose is a serious matter while friction in a hydrant is almost nothing by contrast. Sufficient hydrants should be installed so that 150 feet of hose, from the two nearest hydrants, will reach any fire in the central section of a plant.

If located too close to buildings, it may not be possible to reach the hydrants at the time of a fire, or they may have to be abandoned with the possibility of crippling the entire water system. Hydrants should not be closer than 50 feet from buildings of ordinary height. They should be so located that they will be out of roadways, railroad tracks, and, if possible, out of line of future buildings.

### Interior Fire Extinguishing Apparatus

Valuable fire protection may be secured from inside standpipes and hose, which also have value for protection against exposure as well as for interior fires.

Four things are necessary: A supply of water; installation of pipes, valves and hose; constant maintenance; and persons available who have the knowledge and inclination to make prompt use of such facilities.

Fire plugs for inside service should be at least 1½ inches inside diameter, and so distributed throughout the building that, with 50 feet of hose at fire plugs, at least one good hose stream can be directed on all parts of the interior of the building.

Chemical extinguishers are required for inside protection, both with and without a standpipe system. These are thoroughly standardized throughout the United States, and furnish in incipient fires a small jet of water under high pressure, reaching a point of from 30 to 40 feet from the operator, and lasting, if continued in use, for about one minute. The rules of the fire marshal of Hawaii require one of these extinguishers for each 2500 feet of floor area. Extinguishers should be hung from hooks with tops about five feet from floor level. They are readily upset and partly or entirely discharge if resting on floors or shelves. Annual discharging, cleaning and recharging is recommended, partly to insure the operation of the extinguishers and partly to give employees and others an opportunity to see them used.

### The Watchman

The watchman should be the most important link in a private fire prevention and protective system, but usually is not for the reason that he has not the proper qualifications. While a sugar mill is in operation, the premises are in charge of men of intelligence and ability. When a mill is not in operation, and principally at night, when the most fires occur, the premises are left in charge of the watchman, who, therefore, should be a man physically and mentally sound, alert, intelligent, and of the best morals. He should possess good sight, hearing and a keen sense of smell, all of which are valuable in the detection of fire. He should not be chosen for the job until he has been employed in other positions about the premises long enough to become acquainted. He must be familiar with the location and operation of the fire equipment, must be able to recognize fire hazards and should be given to understand that his is a position of responsibility that calls for something more than a clock puncher. A clock record that shows perfect punctuality shows the watchman thinks his only duty is to punch the clock at the proper time.

It has been gratifying that the construction of the sugar mills in Hawaii has improved materially during the past few years. Many fire hazards have been eliminated, and a considerable amount of fire protection provided. The high standards maintained by our sugar industry, largely through the channel of the Hawaiian Sugar Planters' Association, should also be applied to fire prevention and fire protection.

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## Ditches and Ditch Lining in Connection With Sugar Cane Irrigation in Hawaii*

By J. H. Foss

In Hawaii, not only the main watercourses in the fields are called ditches, as is the custom in other places, but main supply canals, whether open channels or tunnels, are spoken of as ditches. These supply ditches usually convey water from the rough, rainy side of the island to the drier, less rugged side, which is more suitable for sugar cane growing. With few exceptions, the water is taken directly from the streams crossed, without the use of reservoirs. The rainfall is not seasonal in Hawaii, but somewhat continuous throughout the year. This fits in well with the sugar cane irrigation, which is also carried on throughout the entire year in most localities. The lengths of the streams are comparatively short; consequently their flows are flashy, responding readily to heavy, tropical showers.

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Although most of the irrigation is dependent upon this gravity supply, there are a number of localities in which pumping is resorted to to supplement gravity supply, so as to make it possible to carry on irrigation during droughts, which occasionally occur for several weeks, and sometimes even months, at a time. There are a few places that depend entirely upon pump water for irrigation supply.

## Early Irrigation Projects

The first sugar cane irrigation project of any importance in the Hawaiian Islands was built on East Maui under the direction of H. P. Baldwin, in 1876 and 1877. Immediately following this, Claus Spreckels built a similar system on East Maui. In the course of time, similar projects on Maui and other islands were undertaken, especially so after the annexation of the islands by the United States.

The value of water in sugar cane irrigation obviously depends upon the profit from the resulting sugar yield. There has been an average yield of one ton of sugar for every million gallons of water delivered to the Hawaiian Commercial and Sugar Company's and Maui Agricultural Company's plantations. This statement requires further explanation: Independent water measurements and the findings of Maxwell at the Experiment Station, indicate that only about half of this water has reached the cane. The other half is probably lost in reservoirs and service ditches. Furthermore, the resulting yield from a given quantity of water depends upon the season of the year during which the water was applied. Water applied in August may produce twice the sugar yield as an equal quantity of water applied in January. This condition makes the irrigation problem acute in the many localities where two crops are being irrigated in the summer season (the growing and the maturing crops). The demand is thus greatly intensified during this season; and supply and demand play a very important factor in the value of water. This is especially true when considering an additional supply. Additional water has great value when there is a great demand for it, but has little value when there is no demand for it. It may pay to line a ditch which carries the normal dry weather flow, and thereby add to the continuous flow a quantity of water equal to the seepage losses which have been prevented. On the other hand, it may not pay to line a ditch that carries storm water only, because this procedure would merely increase the total flow at times when little use could be made of the additional quantity. Ditch lining is, to a great extent, a problem in marginal return, the profit on the resulting additional yield.

## The Economic Factor in Ditch Lining

The cost of conveying water from place to place in Hawaii, usually from streams to the fields or service reservoirs, comprises not only interest on investment, maintenance, depreciation, operation, cost, taxes, etc., but also the value of water lost in seepage and leakage during transit. Looking at it in this way, it becomes a problem of balancing the value of water annually lost against interest charges on the cost of lining.

The economic capacity of the ditch depends upon the quantity of water available and the demand for that water when it is available. If a ditch having a gravity supply were built too large, the value of the additional water that it is capable of carrying over and above a ditch of the proper size, will not warrant the difference in cost between the two ditches. Only occasionally is there sufficient quantity of available water to make use of this additional capacity, and when that occasion arises, there is a probability that there will be only a slight demand for this additional quantity, because at such times the demand is capable of being filled from many other sources. Now, go to the other extreme: An undersized ditch is one in which the value of the additional water which a proper sized ditch can carry will warrant the difference in cost between the proper sized and undersized ditches. An over or undersized ditch may represent a tremendous money loss.

It is therefore highly advisable to make a study of the quantity of water available, the demand for water, and to what extent these two are synchronous. The important work which is being carried on by the Division of Hydrography of U. S. G. S. in these islands, is furnishing us with a continuous record of the flow in all of our important streams. It can be assumed, with some degree of certainty, that the average flow conditions of the past several years (say twenty), will be repeated in the next several years. The early ditch work on the islands made it quite necessary that stream flow data be obtained by the concerns undertaking the project, which usually extended over only a short period of time just previous to undertaking the project. There always existed the possibility that the data obtained did not cover average conditions. The data of the Division of Hydrography, U. S. G. S., of course, gives us something more ideal upon which to base our estimates, as a rule extending over a longer period of time, are more accurate, and available when wanted. The question arises, how long a period of time should we be satisfied with in this kind of work? When will additional hydrographic data add little or nothing to the results? The writer ventures to limit this to thirty years. The Hydrographic Survey Department should receive hearty support from the Territory for many years to come, so as to obtain valuable data for these islands.

On the other hand, the *demand* for water is fairly well known in a general way, considering the present methods of irrigation. Of course, if it were possible for the cane to withstand periodic shortages in the gravity supply by supplementing this supply with pump water, there would be a greater demand for the flood water.

## Capacity of the Ditch

The capacity of a ditch depends upon the cross-section and grade, and the degree of roughness of the wetted perimeter. An excessive grade will produce too great a velocity in the water, which will erode the sides and bottom of the ditch. Of course, a masonry-lined ditch will withstand higher velocities than an unlined ditch. The maximum velocity for unlined ditches should be about three feet per second, preferably not greater than two feet. Of course, this again depends upon

the nature of the material through which the ditch is excavated. Masonry-lined ditches withstand velocities of from six to ten feet per second, provided the water carries no grit. It is important that the water in masonry-lined ditches be comparatively free from grit. There are instances on East Maui where grit-laden water running at a velocity of about four or five feet a second eroded the floor of the ditch about one inch in eight years' time. Taking this into consideration, it will be seen that comparatively larger investment is warranted in preventing sand and gravel from entering masonry-lined ditches. In the most recent ditch construction on East Maui, provision has been made to strain the water as it is taken from the stream, so as to remove rock and large gravel. The finer material is being taken out by passing the water through a settling basin. It is reasonable to believe that it is this fine material which erodes the masonry-linings, because the coarser material is not carried along by the ditch flow. It is merely deposited in the ditch near the intake, and causes considerable trouble and expense in having it removed. The stream gravel and sand have to be reckoned with, especially in the case of masonry-lined ditches. The grade of the better East Maui ditches is a slope of about one foot a thousand, which produces for the usual ditch cross-sections a maximum velocity of three feet per second in unlined ditches and six feet per second in lined ditches. Where a ditch derives its water from several streams which it crosses, the problem presents itself of increasing the capacity of the ditch as additional streams are taken in. This complicates the hydrography of the problem oftentimes, because these streams may not all rise and fall at the same time. They may be out of synchronism. A study of their flows over several years' time will furnish data for solving this problem, so that good average conditions can be obtained.

## Unit Construction

Since sugar cane irrigation is continuous throughout the year, there is demand that the supply ditches be continuous in their operation. This makes it very difficult to make repairs. Why not follow the scheme used in making machinery layouts, viz.: construct the ditch system in units? In other words, build two smaller parallel ditches instead of one large one. In times of small flow merely use one of these two ditches, thus making it possible to have the other shut down for repairs if need be. There is a possible additional argument in favor of the double unit ditch system. One of these ditches could be completely lined so as to be fairly water-tight, and be used for carrying the dry and normal weather flow; whereas the other ditch could be unlined and used to carry flood flows. Temporarily the unlined ditch could carry the normal or dry weather flow, should the lined ditch require repairing. Both of these ditches should deliver water at an elevation that would cover the fields which either are to irrigate. On East Maui, in a general way, each plantation has an upper and lower level supply ditch. This, however, does not fulfill the function of the double unit system outlined above, because the low-level ditch in each case does not deliver water to the plantation so that it can be distributed by gravity to the upper fields.

It is desirable to arrange ditches with overflows at points at which the waste water will do no damage, and yet at sufficiently close intervals to prevent the ditch from overtopping its banks during flood conditions. Overflows call for a "free board" on the ditch. The amount of desirable free board depends upon the length of the waste ways or overflows. Long overflows will discharge a given quantity of water for a much shallower depth on the crest than a short overflow. It is this depth of water on the crest that decides the amount of free board necessary in the ditch. Short, infrequent overflows call for greater free board. It becomes a problem in which the cost of additional overflow capacity is balanced against the decreased cost resulting from constructing the ditch less deep. Free board from three to six inches is not uncommon.

## Protecting Ditch Banks

There is another method of protecting the ditch banks from being overtopped in times of flood water, which has been tried to a limited extent on East Maui, viz.: the use of automatic intake gates. These are actuated by floats which close the gate when the main aqueduct is full, or partially close the gate so as to prevent the bank of the main aqueduct from being overtopped. Of course, this same operation can be approximated by hand-operated gates. In the hand operation, if the ditch tender is too conservative, he will keep the intake gates too closely set and run the danger of the water not being taken in when there is room in the main aqueduct for it. On the other hand, if the ditchman has not set his gate sufficiently close, unexpected showers may cause more water to be introduced into the main aqueduct than it will carry, and thus cause an overtopping of ditch banks. This is undesirable because there is a danger of the bank being washed out and the ditch breaking, or even if this does not happen the water wasted may damage property below the main aqueduct by flowing where it is not intended it should. Automatic intake gates have additional value, possibly their greatest value, in preventing much grit from entering the main ditch by automatically closing at times of flood waters, which are usually heavily laden with sand and gravel. These gates, although automatic in operation, require considerable maintenance attention to keep them in running order, and the question arises whether this additional maintenance cost is justified.

## Ditch Lining

*Ditch lining* is an important phase of ditch construction. In this connection, the important thing to decide is: "Will the saving of water warrant the cost of lining the ditch?" Of course this depends upon the amount of seepage and leakage that is prevented by the lining. In planning a new ditch, the seepage and leakage losses cannot be foretold nearly as accurately as they can be measured in existing ditches. The losses which will exist in the proposed ditch can only be estimated by assuming that they will equal those in an existing ditch through similar material. It appears to be good business before deciding upon lining a ditch to determine by measurement, the amount of seepage and leakage losses,

in the existing ditch, the lining of which is under consideration, or those in a ditch similar to the proposed ditch, as the case may be, and make an estimate of whether the cost of lining the ditch will be repaid by the water saved. In carrying on these water measurements, it would be well to divide the ditch up into sections and determine the seepage and leakage losses in each section, thereby locating the portions of the ditch leaking most. It may thus be found that it will only pay to line certain portions, the most leaky ones first. Other conditions being equal, the discharge end should be begun first. This is based on the theory that the water becomes more valuable as it is conveyed along the ditch and nears its destination. This is particularly true of ditches that take in their supply from the various streams crossed. At flood times the last stream or the last few streams crossed may have sufficient flow to fill the ditch. Under these conditions, lining in the lower section would be working 100 per cent of the time, whereas the lining of the main aqueduct in the section in which the first stream is taken in, is only in useful operation a portion of the time.

Although the principal function of ditch lining is to prevent seepage and leakage losses, it does decrease the operation and maintenance of the ditch, in many cases by preventing vegetation from growing on the banks of the ditch, which would otherwise call for labor to clear it away. It also prevents erosion of the banks and gives greater carrying capacity for a given cross-section and grade of ditch.

## Types of Ditches

Various types of lining have been employed: cut stone set in mortar, plaster lining placed by hand or by cement gun, pre-cast concrete slabs, concrete lining cast in place either by the use or non-use of forms. Other types of lining have been tried, only to a very limited extent, such as asphalt and crude oil. In former years, when labor was cheap and there were few roads through the rough country traversed by the ditch, cut stone lining was employed to a great extent. There is always a probability that this type of lining will not prevent as much of the seepage and leakage as other forms of lining. In other words, the lining itself may be leaky, depending upon the care with which it has been placed. It has this advantage: cut stone will resist wear of grit-laden water quite successfully, and this type, well backed with concrete, is therefore being employed where excess velocities are to be combated, such as in ditches having excessive grades. Cut stone lining in out-of-way places obviates the necessity of transportation of a great deal of the material that concrete lining would call for, and therefore fills a want in such places.

## Pre-Cast Ditches

The use of pre-cast concrete lining is justified in places where it is not feasible to close down the ditch for a long enough period of time to give concrete cast in place sufficient time to harden. Pre-cast concrete requires less form work than concrete cast in place behind forms, but has this objection: At least this is the experience of the Wailuku Sugar Company, which carried on this

method of lining quite extensively six years ago. There is a far greater tendency for the ground water to get behind the pre-cast concrete, and should the ditch lower suddenly, it would force the lining away from the bank. This is probably due to voids behind the lining. To overcome the tendency of the wall lining to tip into the ditch, the Wailuku Sugar Company has put in pre-cast concrete struts across the ditch at intervals, thus holding the two walls apart and preventing them from moving inward. Unlike pre-cast concrete lining, concrete lining cast in place shows very little tendency to fail, because of water pressure behind the concrete at times of low water in the ditch. Other things being equal, pre-cast concrete lining costs more than concrete cast in place, due to the additional cost of placing the slabs of concrete after they have hardened.

### Plaster Ditches

From 1912 to 1917, a large percentage of the ditch lining on Maui was done by the plaster method. Plaster was supposedly about three-fourths inch thick, placed either by hand or by cement guns, embedded in which was a poultry wire mesh, acting as a reinforcement. It is almost impossible to tell today whether a given portion of this plaster lining was done by hand or by the cement gun process. In either case, it has been more or less of a failure. This kind of lining on the floors of tunnels and open ditches has almost entirely disappeared. Initial failure of a floor thus lined may be due to the fact that it has not withstood walking on it. After cracking, the water gets under the edge, and a high velocity will cause the floor lining to roll up in a manner similar to a roll of carpet, and be carried down the ditch. The sides withstood the test of time somewhat better but in many cases large portions of the lining on the sides have disappeared. It would appear that a sudden decrease in the depth of water in the ditch will, in many cases, leave water behind the plaster lining, which will force the lining off the side of the ditch. (Possibly this same action caused the first breaks in the floor lining.) Of course, after the floor has gone there is little chance of getting unbalanced hydrostatic pressure behind the wall lining. This accounts for much of the wall being intact, but doing little useful work.

There is a probability that plaster lining would have proven more satisfactory if more care had been exercised in doing the work, but the cost would have been greatly increased. One of the difficulties encountered in plaster lining is to get the plaster of uniform thickness. If the sides of the ditch are not perfectly planed, there is always the possibility of having the plaster thick in one place and very thin in another. In fact, it is almost impossible for the plasterer himself to tell how thick he is getting the plaster, because, after the surface is covered there is no feasible way of telling how thick the plaster is.

The method used in lining the Gage Canal of Southern California, a number of years ago, might have been successfully employed, viz.: by bringing the ditch sides to a practically plain surface, and then using guides to assure uniform thickness of plaster. Of course, the extremely thin places in our lining fail first. There is another reason why ours have not been as successful as the Gage Canal. In Southern California they have seasonal irrigation. Before starting up irriga-

tion for the season, the lining of the ditch is gone over from end to end, and put in good repair, whereas with us, this is practically impossible because the ditches cannot be shut down for a sufficient length of time to carry on this kind of work. The claim that the cement gun places the mortar immediately after the water is introduced, and that it is not disturbed after it commences to set, and thereby produces a stronger plaster than that placed by hand, is not always true in practice. The man operating the cement gun does not always build up the portion of the lining to the desired thickness, before passing on to a new place. In other words, he may go back over work that has been placed several minutes previous to build up the plaster to the desired thickness, and in so doing disturb the initial set of the underlying portion. One of the principal costs of plaster and concrete lining is that of cement. Usually there is as much cement in plaster an inch thick as in concrete three inches thick.

## Concrete Ditches

Concrete ditch lining which has not been subjected to high velocities of grit-laden water and the aggregates of which are hard, sharp material, has stood the test of time. Coral sand as an aggregate does not give a surface that resists wear as well as hard, sharp, crushed rock sand, neither does it produce a strong concrete. Its comparatively low cost in many localities, however, justifies its use if the lining is not to be subjected to excessive wear. Pump water and gravity water which have been standing in reservoirs will not contain grit in such quantities as to erode masonry-lining having coral sand as an aggregate, providing the velocities are moderate.

The cross-section of a ditch is determined by the conditions which have to be met in each case. If the aqueduct is tunnel, the walls are nearly vertical; if, open ditch on a steep side hill of hard material, the walls are only slightly sloped; if open ditch across comparatively flat country, the walls are usually given considerable slope. In casting concrete lining on nearly vertical walls, forms are used, usually on the water side only, backfilling where excessive excavation (as in hard material which blasts out unevenly) would otherwise give too thick a lining. It is well to make this backfilling of clean hard rock, if available at moderate cost, so that the concrete will bond with it, thus making it possible to reduce the thickness of concrete and still have a masonry wall of normal thickness. Where conditions are such that it is feasible to give the sides of the ditch considerable slope, a thinner lining can be used than would otherwise resist a possible hydrostatic pressure produced by water which might collect behind the lining, followed by a sudden drop in the ditch flow. Since the floor has to withstand the greatest wear, by material being rolled along it, logically, it should be made thicker and of better material than the sides. In addition to this precaution, it is well in some cases to give the floor the form of an inverted arch so that any rolling and sliding grit is distributed more evenly over its surface. If the floors are flat, there is a tendency for the wear to be concentrated along the angle between the wall and floor.

There are several advantages in casting concrete lining in place without the use of forms. This can always be done on the floor and on sides of sufficient slope, say a minimum of 1 to 1. Not only is there a saving, due to the non-use of forms, but a great advantage in being able to apply the plaster finish to the concrete before it has begun to set, and thereby insure a bond between the two. When the plaster finish coat is applied to the concrete after it has set, which is necessary if forms are used, there is much more of a possibility of not having a perfect bond. There is a tendency for plaster finish exposed to the sun to spall off in patches, not necessarily the first few years, possibly after it is several years old. This is probably due to unequal expansion and contraction of the plaster and concrete, resulting from variations in temperature. This tendency is aggravated if the mortar composing the plaster is richer in cement than the mortar-aggregate of the concrete. Of course, floors can and should have the finishing coat applied immediately after casting the concrete, and special care should be taken in finishing with a thick coat fairly rich with cement, so as to withstand the excessive wear to which they will be subjected. A rich plaster coat on the floor, if applied before the concrete is set and well worked in, will not spall off, especially if at all times protected from changes in temperature by continuous flow of water in the ditch.

## Expansion Joints

Joints to take up expansion and contraction, due to changes in temperature, are advisable to open ditch lining under most Hawaiian conditions. Otherwise unsightly cracks will appear at various intervals. In localities and under conditions where there is only a very slight change in temperature the year round, this is not true. For example, non-reinforced concrete tunnel lining, in the Hawaiian climate, will not crack, even if no expansion joints are provided. Non-reinforced concrete lining in open ditches under ordinary conditions in Hawaii will not crack if expansion joints are located at about fifteen-foot intervals. These may be some kind of slip joints to prevent leakage through them, or they may be a plain construction joint having strips of roofing paper separating the two adjacent blocks of concrete lining. If placed at the suggested intervals, these plain joints will open so slightly, due to contraction, that the leakage through them is only slight. On the other hand, expansion joints placed some distance apart, such as at either end of a reinforced concrete flume of one hundred feet or more in length, will require some specially designed slip joint or flexible diaphragm joint to prevent leakage, due to the excessive opening of the joint when the temperature of the concrete is lowered slightly.

The exposed surface of the concrete lining may be left without any finishing plaster coat. However, it is usually advisable to use some kind of a finish. Unless there has been an excessive quantity of mortar aggregate used in the concrete, there will probably be considerable seepage through unfinished concrete. The strength of concrete is directly dependable upon the strength of the mortar aggregate. To get a strong, dense concrete requires excessive mortar rich in cement. A less dense concrete, but just as strong, can be made with a less quan-

tity of this mortar aggregate with a resulting saving in cement, and cement is the costly item in concrete work. An economical way to get the desired result in ditch lining, is to make a strong, less dense concrete and finish it with a more impervious plaster coat. This will work out satisfactorily in case the plaster coat is applied on the fresh concrete and a perfect bond is thus obtained. Of course, this procedure necessarily presupposes that the concrete is cast without forms.

### Grout-Painting

*Grout-Painting* is another method used in finishing the exposed surface of concrete lining. It consists of applying a cement grout with a paint (or whitewash) brush to the surface of the hardened concrete, which has been cast behind forms, and from which the forms have been removed. This grout may be a wet mixture of cement and sand or merely cement alone. Very seldom will this grout stay on the concrete any great period of time, probably due to a lack of a bond between the two. On the other hand, there is a possibility that the surface pores of the concrete are filled with grout which continues to play an important part in making the concrete impervious. The efficiency of grout-painting is doubtful because it does not produce the hard wearing surface that is obtained by using a plaster finish.

Cement mortar plaster used with or without a concrete backing for ditch lining may have its surface finished in two ways: (1) a "glazed" smooth surface, produced by the use of a steel trowel; (2) a sand finish, produced either by the use of a wooden trowel or by brushing the surface before it is set with a whitewash brush. A "glazed" surface exposed to the sun will tend to become checked with a great number of surface cracks; whereas, under similar conditions, a sand finish does not have this tendency. Probably the sand finish produces sufficient shade and shadow effect to prevent the surface from becoming as highly heated as the "glazed" surface. Accordingly, it is well to give a sand finish to an open ditch lining, and a steel trowel finish to a tunnel lining. The smooth finish produces a slightly greater carrying capacity for a given cross-section than the sand finish.

Of the various ditch linings, considered above, the most satisfactory from cost, maintenance and utilization point of view, is the non-reinforced concrete, cast without forms and finished before it begins to set with a cement mortar. Of course, this method can only be used where it is feasible to give the ditch banks slopes of one to one or flatter. When a power-driven concrete mixer is used, when material is delivered to it in cars, and when the entire equipment so moves along, as the lining advances, that the fresh concrete is discharged from the mixer near enough at hand to obviate the use of wheelbarrows or carts, the labor required to place a 3- or 4-inch lining varies from 100 to 140 square feet per man a day.

After all the foregoing statements concerning ditches and ditch lining, it must be admitted that each project or portion of a project is a problem in itself, and no hard and fast rule can be laid down as to location, size, grade and kind of lining to use.

# Genetics and Its Relation to Cane Production*

By F. G. Krauss
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A questionnaire was sent to twenty-five representative members of the Association of Hawaiian Sugar Technologists, to which sixteen replies were received. The following are the names of those who contributed information. After each name appears an index number. These numbers are used throughout the text in place of the names, for the sake of brevity: A. D. Shamel (1), L. D. Larsen (2), Y. Kutsunai (3), Frank W. Broadbent (4), W. W. G. Moir (5), H. P. Agee (6), W. P. Alexander (7), Wm. Wolters (8), C. E. S. Burns (9), J. N. P. Webster (10), Douglas Cooke (11), John C. Thompson (12), J. S. B. Pratt, Jr. (13), John H. Midkiff (14), and C. F. Poole (15). The questions and their answers follow:

**QUESTION I. (a) What are the most important problems in your sugar cane improvement through breeding? Please enumerate.**

ANSWERS: To determine the heritability of characters and of variations of the various varieties of cane (3).

To combine the most desirable characters of various existing canes in new sorts. Characters sought are, *adaptability, heavy cane yields, good quality ratio,* and *high degree of resistance* to disease (mosaic and eye spot (4)) and injury (3). Desirability of having a good substitute cane on hand (4).

The problem is to secure an understudy to H 109 which will have equal cane tonnage, but which will also be immune to the eye spot leaf disease and *be a better, early* ripening cane (7).

To produce a high yielder, . . . a good ratooner, as we ratoon a great deal, . . . . a cane which is disease resistant . . . a cane which can substitute any one of our standard varieties such as H 109, or D 1135, in localities where they do the best (8).

To develop a cane equal to or better than H 109, but with a quality ratio like that of Lahaina, to create better uniformity in the stand and stalks of present standard varieties (10).

The ultimate object of all cane breeding is to find varieties which under certain conditions of environment will produce sugar with greater profit than the so-called standard varieties hitherto grown. This result is obtained by either increasing production per acre, or with hardier canes, producing sugar at less cost per unit, . . . (conditions of environment enumerated in detail). . . . Whether a seedling will produce sugar with greater profit than the former standard variety is determined by its degree of adaptability to any given set of conditions. A single change in these conditions may necessitate a different variety of cane (4). . . . Determining the variety most suited to any given environment (11).

To secure pure line strains of the variety in question through progeny tests. To secure superior types from these pure line strains, after a series of progeny tests extending over several plant crops and ratoons. To secure possible mutations superior to the general run of the progeny under observation and to eliminate undesirable mutants. To secure larger yields through type selection rather than by a cumulative plus variant selection. To secure strains that will be resistant to Pahala blight and other local diseases (12).

* Presented at Fourth Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 26, 1925.

Our biggest problem at Waialua is to find some cane that will give us the same yield that we get from H 109 and which is also resistant to eye spot. It is our belief that we are more likely to find this cane among some of our new seedlings, rather than by selection within H 109 (14).

At Waialua we are severely hit by eye spot disease and we believe it is only a question of time when we shall have to find some new variety to replace H 109. That is the end we are working towards (14).

**QUESTION I. (b): If you are practicing vegetative, selective breeding (bud selection), what plant characters are involved in your selections? Please enumerate each character considered and state the extent to which these characters are correlated.**

ANSWERS: Selection is based on cane yield and the quality ratio. These two characters seem in general to be correlated. In case the cane is not weighed, the volume of the cane is judged. The weight and the volume are very closely correlated (3). Freedom from disease and weight of cane in pounds per foot of row (4).

Type of tillering (stooling). Earliness of tillering. No definite correlation data have been secured but good indications of correlation have been observed (5).

To date plant characters, **per se** (by themselves) have not been involved. Weight of cane per acre has been the basis upon which progenies have been selected. We are working with mutations showing different physiological characteristics, but are not able to report any definite correlations (7).

We first select outstanding stools having eight or more stalks each of uniform size. Greatest yield of sugar per acre over a period of years is what we are after. We want a cane that stools out early in order to close in quickly and yet carries through to harvest without going back (9).

So far no other character has been found that can be correlated with sugar content except possibly vigor of growth (11).

Plant characters noted in selections. Type of stool which classifies the stools as erect or upright, semi-erect, and recumbent and intermediate grades between the extremes. Shape of stool in which stools are classified as standard, fan, and birdnest types, the standard types of stool being most desirable and found to a large extent erect and upright. The recumbent type is associated more with the birdnest type of stool. Manner of stooling which includes the manner in which the sticks originate from the seed piece or appear above the ground, the compact mass of stalks originating from a single eye being more desirable. Uniformity of stalks is also considered in the first selection of stools (12).

We expect to do more or less bud selection work in the near future. We will then stress eye spot resistance correlated with satisfactory sugar yield.

**QUESTION I. (c): Has your selective breeding, either in bud selection or among your hybrid seedlings, as well as mutations, in either or both materials, progressed far enough to establish definitely improved lines in the qualities sought after, and to what extent?**

ANSWERS: It is probable that the sugar cane varieties of the future will be those which will be hybrids between hardy types or species of cane and the group or species which includes most of our standard canes of today; or, better still, progeny of these hybrids in which the hardy species or type has been diluted until we have quarter-breeds, eighth-breeds and possibly sixteenth-bred canes.

In this class of work we have been severely handicapped through lack of the best breeding material and we will remain under this handicap until we successfully establish in Hawaii the Kassoer variety (and other canes of its type) which gives such promise in this work.

The earliest work in producing hybrid canes that we know of is that of Kobus in Java dating from 1897, or thereabouts, when he crossed the standard canes of Java with Chunnee, a North Indian variety, for the purpose of obtaining relief from sereh. Some of the P. O. J. canes, such as 36 and 213, which are making such a record for themselves, are the

result of this early work of Kobus. Later, Kassoer was used in Java as a breeding cane, Kassoer being a wild hybrid between *Saccharum spontaneum* and *Saccharum officinarum*.

From a breeding standpoint Kassoer offers more interest today than any other hardy cane variety. In the absence of this cane we have struggled during the last few years using our so-called Uba (which is not the Uba of Natal but probably Zwinga or some other inferior type) and our efforts have had some success. From comparatively few hybrids we have some commercial possibilities. If we could have had thousands of hybrid canes to select from instead of a few hundred or so our chances would, of course, have been better, and it is the readiness with which Kassoer lends itself to breeding work, as compared with Uba, that is one of its attractive features. From crossing and recrossing Kassoer in Java they now have some vigorous large stick canes which are attracting attention on account of their hardiness and drought resistance. Among them are P. O. J. 2714 and 2725, twin canes from the same arrow, selected from 25,000 seedlings, and possessing the following interesting pedigree:

1. GLAGAH (⅛) (*S. spontaneum*)
2. BLACK CHERIBON (⅛) (Louisiana Purple)

} Kassoer (¼)

3. BLACK BANDJERMASIN (⅛) (Black Cheribon or Louisiana Purple)
4. LOUZIER (⅛)

} P. O. J. 100 (¼)

} P. O. J. 2364 (½) { P. O. J. 2714 and P. O. J. 2725

5. BANDJERMASIN (¼) (Striped Preanger or Louisiana Striped)
6. FIJI (¼)

} E. K. 28 (½) { (Selected from 25,000 seedlings in 1917)

We trust that in a few years we will be able to show Hawaiian grown canes with equally interesting pedigrees, for we expect to combine the splendid characters of such canes as Yellow Caledonia, Badila, H 109 and D 1135 with the hardiness and disease resistance of such canes as Uba and Kassoer. This is the objective in our cane breeding work which interests me the most. We are working for commercial canes of high weed-suppressing ability, strong ratooning power,—those which will make the most efficient use of the essential factors of sugar production which we have heretofore enumerated: Man-days of labor, Acre-inches of water, Acres of land, and Acre-months of growing time. This involves, as a matter of course, disease resistance or immunity (6).

Some of the hybrids have established improved lines to the extent that they are replacing the older varieties (3).

No (4).

It has puzzled me that in spite of the thousands of seedling canes that have been raised since H 109 was "discovered" we have apparently made little or no progress in the isolation of a cane that would be as superior to H 109 in any quality as H 109 was superior to Lahaina in a lot of qualities. Since H 109 came to light it would seem that practically all island efforts in cane breeding were based on the idea of propagating large numbers of seedlings with the hope that we might have the "luck" to again obtain a superior one. (Our technique has been boiled down to a fine point, thereby proving some progress, but a principle or rule of actions for making crosses based on proven genetical procedure is lacking.) (4a.)

In *seedling* work, several promising canes have been secured that are equally as good as our standard varieties under certain conditions. In *bud selection* work, no conclusive data have

been secured, but improvement in planting material has been noticed as a result of this project (5).*

We think we have several canes that at least equal H 109 (9).

It is hoped that with the bringing in of the Java seedlings further progress will be made along the lines of disease resistant cane.

Several hybrid seedlings have been grown at the Station which show decided improvement over former standard varieties. H 109 is now planted in place of Lahaina on the lowlands, and several Tip and Uba seedlings have been developed that may take the place of D 1135 and Tip canes on the upper fields. H 109 itself will probably very soon be replaced by its own offspring or those of Lahaina.

With bud selection improved lines have not yet been definitely established (11).

Results from selective breeding. Selective breeding, either in bud selections or among our hybrid selections as well as mutations, has not progressed far enough to establish definitely improved lines in quantities sought after. Bud selection requires more attention than can usually be given to that phase of the cane industry, so much depending on the proper examination of the progenies when a year old (12).

We have found one or two seedlings that seem to give fair returns and at the same time to be quite resistant to eye spot (14).

. . . We have just finished five years of study of this problem in sugar cane. I feel very sure that notwithstanding many disappointments in the pedigree selection progeny tests as much progress has been made in sugar cane bud selection work as was made during the same length of time in our citrus work. I believe that with five more years of concentrated and intensive effort the pedigree sugar cane work can be brought to the same stage of commercial value and utilization as has been the case in the citrus during the first ten years of our work (1).

**QUESTION I. (d): 1. What are the most outstanding mutations (sports) that have thus far been discovered? 2. Do the newer seedlings or old established varieties show the greater tendency to mutate in vegctatively propagated material? 3. Are mutations most likely to occur in the plant crop or any succeeding ratcon crop? 4. Are more mutations found in favorable conditions than in unfavorable conditions? 5. Do different cultural conditions appear to exert influence upon mutation ability? 6. In what quantitative, visible characters does the plant most frequently mutate, and to what extent, if any, do these characters correlate with higher total sugar yields, either qualitatively or quantitatively?**

ANSWERS: (d). 1. Rose Bamboo, Yellow Tip, Striped H 109, Striped Yellow Caledonias, Striped D 1135, White D 1135 (3).

A few color mutations (4).

We cannot at this time designate any sports as outstanding, since they are now only in the first planting and only a few months old (7).

We have found several cases of Striped D 1135 in ratoon cane. So far we have not noticed any in the plant cane. This may simply be a case of missing such a mutation or sport in the plant (cane).

No outstanding mutations have so far been discovered (9).

No outstanding mutations have been found, all mutations found this year being now planted out with the parent varieties of the mutations. Several mutations have been found this year with the Manoa Tip seedlings and 8900 series as well as the 1923 Oahu propagated seedlings. Newer seedlings show the greater tendency to mutate in vegetatively propagated material than old established varieties. Mutations occur quite frequently in plant cane, but whether they occur more frequently in later succeeding ratoons has not been noted here. As far as I have noticed, adverse growing conditions exert a greater influence upon mutability. Has not been noted (12).

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* Alexander, of Ewa, makes practically the same remarks.

The newer seedlings seem to show greater tendency to mutate. We have found more mutations in the ratoon crops, but this may be simply because we have not observed them closely enough. We have not found that cultural conditions make canes more or less mutable (14).

(d). 2. Do not know. More mutants were found in H 109 than in Yellow Caledonia, but this difference may be due to the relatively larger amount of labor spent in looking for mutants in H 109 (3).

I believe that the newer seedlings show a greater tendency (to mutate) (4).

Not enough work done to say definitely yet. . . . (5).

We have obtained sports only from H 109 (7).

(d). 3. Do not know, but plant crop is preferred in selection work (3).

No data (4).

Mutations may appear just as readily in plant or ratoons (5).

We have obtained about 75 per cent more mutations from plant fields. This indicates perhaps that plant crops show a greater number of mutations than succeeding ratoons, but beyond this we cannot say, not having made a study of this point (7).

(d). 4. Do not know (3).

No data (4).

Environmental factors have greater influence than anything else (5).

No data (7).

With D 1135 it has been noticed that this cane is very apt to mutate where conditions are severe, as when growing on palis, or where water is a limiting factor (10).

(d). 5. Do not know (3).

(d). 6. Do not know of ever seeing a quantitative mutation, though such appears to be the object of selection. On the other hand, I have seen qualitative effects such as color mutations (4).

The only visible characters that are known to be definitely mutable are color and markings of stalks; type, color and shape of leafy top; and size of stalks and stool in relation to general stature. Yet these characters are correlated, some qualitatively and some quantitatively with sugar yields. For example: Caledonia Ribbon, a color mutation of Yellow Caledonia, has always had a somewhat better quality ratio than Yellow Caledonia, but in tonnage of cane it is slightly lower. Red Tip, the solid, red-colored stalk-sport of Striped Tip, has always been known to be very inferior in tonnage of cane. Yellow Tip, the solid, yellow colored stalk sport of Striped Tip, may be readily distinguished in type of growth and leafy top characteristics and in many localities is found superior to Striped Tip in yield. Black Tanna, the purple mutation of Big Ribbon, is lower in yield than Big Ribbon and is not suited to as varied conditions as is Yellow Caledonia, the yellow mutation. White D 1135, a yellow mutation of Striped D 1135, is poor in yield. Hairy Yellow Caledonia is a very inferior cane as compared to Yellow Caledonia (5).

"(7)" mentions several of the above observations.

Our mutations have not been under observation for a sufficient period of time to attempt to correlate mutation characteristics with sugar yields (7).

The visible characters in D 1135 when mutation takes place, consist of a narrow stripe, either dark purple or green, the former being more easily found. . . . Such conditions are inferior as to size of stalk and growth in some cases (10).

**QUESTION I. (e). 1. How are your progeny tests conducted, and how do you control the environmental influences under which these cultures are grown? 2. Do you feel that your bud selection work has resulted in the establishment of definitely improved strains or varieties or that you are making satisfactory progress towards your goal? 3. What appear to be the greatest difficulties of the work in hand? 4. Can you suggest any improvement over our present methods?**

ANSWER: (e). 1. Progenies are given ample room to develop so that their relative (inherent) capacities only become the limiting factor (3).

Progeny tests are conducted on a field scale where the environmental influence is under no more control than in the usual plantation cane field (4).

Progeny tests are conducted under as near average plantation conditions as possible. They should *not* be given the very best treatment. If possible they should be given treatment below average and allowed to ratoon before selection. All work (selection?) should be done in material that has been allowed to reach maturity—that is, two years of age (5).

The progenies are planted for comparison . . . adjacent to plots of ordinary plantation (H 109) cane. (It is very important that the seed for these checks be obtained from cane of the same age and environment as the progeny material.) Fertilizers and irrigation are applied as uniformly as possible to progeny and control plots. Even so, variation in stand and soil difference are very great and tend to overshadow what may be hereditary influences (7).

Our progenies are all planted with checks of H 109 for comparisons (9).

We avoid, if possible, varying environmental influences. The plot chosen for progeny work must be practically level and the soil as uniform as possible. Only such seed is planted as will give even germination, since a good stand is an essential. Uniformity of germination is further controlled by planting in boxes and setting out uniform plants.

An attempt has been made to avoid unevenness of light, aeration, and water by placing the plants in rows five feet apart from center to center. The amount of water given is under careful control. Likewise fertilizer. Border rows are not included in harvest data (11).

**Progeny Test Areas**

The usual practice has been to select stools in a field and plant the seed pieces of each stool or progeny separately, spacing the seed from 6 to 12 inches apart. The cane from which the seed or stools were selected was generally one year old or thereabout. However, a change has been made in this year's selection. In selecting for progeny planting from the plantation fields, it was thought advisable this year to select stools and seed from the best fields and from cane which was being harvested. The idea was advanced that only when a field is being harvested, is one able to judge the kind of cane correctly. This method eliminates the usual stripping which is necessary when the selection of stools is done in year-old cane. However, the general study of the stools and judging the stools selected according to their superiority over the surrounding stools which is possible with young cane where the outstanding stools are marked and cut for progeny planting, are wholly impossible with selection in two-year old cane. The method employed this year will probably bring far better results as a whole, although progenies will be compared on a smaller scale, single stools representing progenies where formerly each progeny occupied a certain area or a part of a row.

Where possible, the best stools have been selected, but due to the great difficulty experienced especially with cane fallen down and covered with trash it has been impossible to select the best stools in comparison with the surrounding stools. However, a certain standard and type of stool was first adopted for the field, this being the result of careful examination of stools in the burnt area being harvested. After satisfying oneself with the best type of stool in the field, as many stools coming within range of the selectionist's vision and examination were selected and planted out.

When planted out, all stools having the same number of stalks were planted to the same area. For example, all of the stools with six stalks each were first separated and planted one stool to a line of a certain length, depending much on how great a spacing was allowed between seed pieces. The whole width of the plot was planted to stools with six stalks to the stool, when a path of three to five feet was marked down along the back line of the first section as outlined in the diagram. Another section of lines of the same length was then planted, to stools of six stalks each. The length of the lines was increased whenever stools of more stalks were planted.



This method of planting progenies not only facilitates the harvesting of progenies but also eliminates the more complex method of staking out progenies and the heavy expense of stakes. By this method only a few good stakes are required, where hundreds were formerly required, back line stakes of old boards being used in the paths between sections.

Besides selecting stools in the harvesting field, effort was made to select the best seed possible for progeny planting. By the best seed is meant seed from what may be termed good, large, uniform sticks above the average. This enabled the selectionist to cover a large area and to get the best sticks in the area examined. Although this method does not enable one to get a progeny growing on a large scale during the first year, it should give the selectionist the best result. The best seed is planted and spaced such that each progeny will be distinctly separated. A greater number of progenies, which represent only the best sticks in the good stools, is the result of such a selection. Such a selection eliminates all the work of harvesting a whole progeny by stools and of calculating the necessary data and the final selection of the best stool in the progeny for further tests, discarding the other stools of the same progeny.

This method makes it necessary to select for further planting after a year's growth, for a careful examination must be made of each individual stool or progeny.

With regard to harvesting progenies this year in two-year old cane, the following method has been employed. Due to the tangled mass of cane, it is wholly impossible to weigh by individual stools, since such a process would incur a heavy expense unless burnt, during which conflagration the stakes would probably be charred. The cane is cut by progenies in the usual way, scaled and computations made for tonnage per acre and the weight per stick whenever possible to count the stalks. The usual method of selecting the stools above the average for the day or over a certain uniform area has been substituted such that another higher average is taken of all of the progenies above the general average of the area or day, and all stools ranking above this higher average are selected for progeny planting. This method raises the average of the field and allows only the best of the progenies to be harvested.

This method is being used in harvesting both plant and ratoons, the ratoons being harvested and planted to check up on the plant cane results.

(e). 2. I believe that our bud selection has resulted in the establishment of improved strains, although we are making only slow progress towards our goal (12).

The data on bud selection are conflicting, and need more time to decide this point (3).

Have no evidence as yet to prove the establishment of a definitely improved strain of cane as the result of bud selection work (4).

Yes, making satisfactory progress, as fast as can be expected (5).

We hope that we are making progress, but often it appears as if we were still far from our goal. Quick results cannot be expected (7).

So far we have not established any definitely improved strains or varieties. We have over fifty progenies extended into areas of sufficient size to give us some very interesting data after they are harvested this year (9).

We cannot say that bud selection has resulted in definitely improved strains because there is still a good deal of variation within progenies. However, the results obtained from some progenies are along the right lines and it is only a matter of time when we will know more about them. Spreading the better progenies out to large areas where environment plays a lesser role and being able to get actual harvesting results is very important (10).

Too soon to state definitely that bud selection has resulted in the establishment of improved strains. One of our Yellow Caledonia progenies seems to have made a very good record, but it needs further test. It was six or seven years after its creation before the superiority of H 109 was proven with any degree of certainty. Perhaps the reason people are too quickly becoming discouraged with bud selection is that they were too optimistic at the beginning (11).

(e). 3. The difficulty of detecting the invisible characters and the masking influence of the environment (3).

A plan of proved merit suitable for use under plantation conditions (4).

The greatest difficulty of the work is the elimination of progenies to a point where proper experimental plantings with checks may be made and not take up too large an area (5).

. . . To be able to isolate (locate) the mutations. (b) To eliminate conflicting environmental influences in tests, so that the inherent qualities can be measured. (c) To prove that the strain is permanent and not instable (7). (Part of this (7) statement was not very clear and interpretation is given, K.)

(1) Inability to recognize mutations other than those of color.

(2) Practically impossible to absolutely control environments.

Our present method of planting the cane in holes spaced five feet apart is our latest attempt at controlling environment.

(e) 4. Detailed genetical study of the cane plant with the view of establishing visible indices correlated with invisible characters may help (3).

If present methods need improvement they probably need a more scientific and accurate control of the details (environment, etc.), all of which, I believe, will take the work away from rather than towards plantation conditions. It appears to me a job requiring special attention (4).

The first recommendation I would make is to study more closely the ratoons of progeny plantings. A second is to work with fewer progenies. A third is to allow all material to go through to maturity before securing yield figures, and the fourth, to study the cane plants in progenies a great deal closer to identify characteristics of structure and habit that are usually associated with different types (5).

Our selections must be based upon some characteristic that is not affected by environment (7).

A closer study of the cane plant with the purpose of correlating visible characteristics with high sugar yield should be made.

Every effort is being made to secure hybrids this year, with varying combinations of H 109, Lahaina, D 1135, Yellow Bamboo, Striped Mexican, Uba, Striped and Yellow Tip and Yellow Caledonia and the Uba Hybrids (12).

As yet no hand pollinization has been practiced (12).

D 1135 appears to be the most favorable stock from which to secure naturally fertilized seed on account of its very receptive female organs and being a heavy pollen forming variety (12).

In case of hand pollinated material, H 109 and Lahaina are found to be the most favorable female parents, while D 1135 and Badila are the best male parents (12).

In cases where both parents are known, the male parent appears to be the most prepotent for the characters sought to establish (12).

No factorial analysis of hybrid progenies has been attempted here to determine the application of the Mendelian law (12).

Seedling work will beyond doubt bring in more promising results in the improvement of our present varieties and strains of sugar cane and in a shorter time than bud selection (12).

In bud selection, progressive selection does much to improve the yields in the shortest possible time, but no further progress above a certain mean is possible through this method of selection (12).

Mutations and type mutations require more experience than any other line and an actual acquaintance with the variety in question. The resulting mutations are pure-line strains of the variety in question, which, if above the general run of the progenies in question, are of vital importance to the progress of bud selection and the improvement of sugar cane. This phase in the improvement of cane requires an actual acquaintance with the types of cane and a longer time to test out the pure line strains and mutations in progeny plantings (12).

With regard to seedling work, hybrids will in all probability bring in the best results, for in this branch only varieties with desirable qualities are used to produce seedling or hybrids. This method does not bring in the numerous seedlings which are to be found with volunteer tassels. Volunteer tassels, however, serve the purpose of securing large numbers of seedlings, but a smaller percentage of desirable seedlings is derived from this source than from the hybrids. However, a greater variety of seedlings results from this source (12).

Self pollinated seedlings are not on the whole the best kind of seedlings for only the qualities of the parent are inherited by the seedlings (12).

Hand pollinated crosses are valuable as a source for deriving seedlings, but it is a more difficult means for securing seedlings (12).

**QUESTION II. (a) 1. If you are raising cane seedlings (hybrids and or "selfs"), what methods do you pursue in securing seed? 2. To what extent is hand pollinization practiced? 3. What parentage (variety) appears to be the most favorable stock from which to secure naturally fertilized seed? 4. And in the case of hand pollinated material which are found to be the most favorable female parents, and which the most favorable male parents? 5. In cases where both parents are known which appears to be the most prepotent for the characters sought to establish? 6. Have you attempted any factorial analysis of your hybrid progenies? If so, do the results appear to follow the Mendelian law? 7. From your experience and observation what methods of breeding, by bud selection (1—progressive selections, or 2—mutations); or through seedling work (3—volunteer seedlings, 4—hybrids, or 5—selfs, or 6—hand pollinization of selfs or crosses) do you consider the most favorable and promising for the improvement of our present varieties and strains of sugar cane? What appear to be the advantages and disadvantages of each of the different methods under consideration?**

ANSWERS: (a) 1. Two methods—hand pollination and natural pollination. (The object of this question was to bring out the detailed technic of pollination.) (3)

From wherever good, naturally fertilized tassels can be obtained (4).

Seed is secured in the field on a large scale from natural hybrids or selfs of varieties desired as parents (7).

We have never raised cane seedlings (9).

Thus far just field collections have been made (12).

We have received practically all of our Field Test 1 seedlings from the H. S. P. A. Experiment Station. We do not produce any of the seedlings ourselves. We seem to get the best results from H 109 stock. The best seedlings that I have seen come from H 109 parent stock that has been crossed through wind pollinization from other nearby canes. This, of course, is a rather hit-or-miss proposition and I have no doubht that in the future the best results will be obtained from carefully worked out hand pollinization (14).

(a) 2. Hand pollination is resorted to when natural pollination is not possible (3).

Have not done any of this (4).

Only in an experimental way so far (7).

(a) 3. H 109, Lahaina, Striped Mexican, Tip canes, and Yellow Caledonia are considered to be the most favored stock for obtaining naturally fertilized seed (3).

Have not had enough experience with the different varieties to say definitely (4).

We prefer H 109 as the female parent (7).

Lahaina and H 109 (10).

H 1801 is outstanding as a variety from which to obtain numerous germinations, probably largely selfs. D 1135 is also worked freely both ways. H 109 has much less tendency to self. This also applies to Tip canes, Striped Mexican, Lahaina and Badila. So in order to obtain field crosses of these with D 1135 it is better to use D 1135 as the male parent, as one gets less selfs in that way (see chart) (11).

(a) 4. Uba as female. D 1135 and H 109 as male (3).

(a) 5. No decision has been reached on this point. Usually the seedlings of known parentage show more female characters than of the male character, and this preponderancy

may be due to a certain amount of selfing, and not due to the prepotency of the female cane (3).

No data (7).

Badila and Yellow Caledonia as female parents seem to be prepotent for high sugar content and vigor of growth respectively (11).

(a) 6. No (3).

No (4).

Carefully planned factorial analysis has not yet been attempted. In first generation Uba hybrids, the Uba characters predominate (11).

(a) 7. Progressive selections: Have no faith in the cumulative effect of bud selection practiced for a short time, but do believe in the repetition of selection for obtaining accuracy (3). On this point, Shamel, in *The Improvement of Plants Through Bud Selection*, p. 3, 1921, states: "The experience and observations of the writer have led him to believe that by continuous selection in isolated strains—[I take this to mean a comparatively fixed or pure strain.—F. G. K.]—the mean of the variation in the selected population may be raised to a point more nearly approximating the maximum exhibitions of the character in the strain."

Mutations: I feel this is the most important, but no method has yet been devised by which economic mutations can be spotted (3).

With the success of H 109 in mind it might appear that seedling work by the natural fertilization of selfs or hybrids offers the best opportunity for the improvement of our canes. On the other hand, when the fact is considered that no very distinct improvement over H 109, among the self-pollinated seedlings, that have been raised since the advent of H 109, it might be better to turn towards methods in which the various phases are under closer control (4).

Seedling work seems to have the greatest possibilities in the improvement of cane production, but bud selection will be necessary to maintain this increased production. Hand pollinization of selfs and the purification of characters, later combining the desirable traits, seems to be the most advantageous method to follow (5).

Seedling work produced our "mainstay," H 109, and we have every reason to believe that we should be able to duplicate the success secured in propagating this wonderful cane. To date no other method in Hawaii has brought forth a commercial cane. This does not mean, however, that we should not give all methods a thorough trial. It is a question whether plantations themselves are prepared to do very careful breeding work involving years of crossing and recrossing. There is no doubt that strenuous efforts at scientific breeding should be made by the Experiment Station as opposed to the "hit-or-miss" methods that are used in securing natural field crosses.

We believe that seedling work offers the best opportunity to obtain better cane varieties (9).

A good deal of work in improving corn has been done by taking two outstanding varieties and breeding pure strains of each. These pure strains were then crossed and the results were gratifying. It seems that this same method could be applied to cane. Naturally it would take some time to get results, but in the end they might easily pay all the expense and trouble incurred (10).

Seedling work has proven value. Bud selection has not advanced far enough to compare with it. The former has 20 years back of it and the latter 5 years. As we see it the two should go hand in hand. Seedling work to produce new varieties with new combinations of characters to meet the varying conditions, and bud selection mainly to keep up what we already have to its original standard. Bud selection in sugar cane is not creating anything new; it is trying to maintain and purify what we already have (11).

Volunteer seedlings are not advantageous, because they may not have the combinations sought, and they are not found when wanted (3).

Hybrids seem to have vigor of growth (3).

Selfs are too weak for immediate commercial purposes. They are valuable for studying heredity (3).

Hand pollination permits the crossing of varieties growing at a distance, but the method cannot be followed on a large scale on account of the labor involved (3).

**QUESTION III. (a) 1. Please describe as comprehensively as possible the technique that you have adopted in your bud selection and seedling work for the development and establishing of better varieties and strains of sugar cane, including methods of keeping breeding records. 2. Have you plans for extending and improving your methods of cane breeding, and what do you consider the most important reform, if any, that should be inaugurated to better bring about the results we are all asking—the development of more productive and better varieties and strains of sugar cane for Hawaii than are now being grown, or that at least may take the place of the best sorts, should any unforeseen difficulty befall them?**

ANSWERS: Bud Selection: Stools with many, uniform, vigorous sticks are selected, cut for seed, and planted. The resultant crop is cut, weighed and the juices are analyzed. The high sugar yielders are selected for further trial. The selection is repeated until satisfactory results are obtained. Sometimes ratoon crops are tested (3).

Seedlings: The desirable tassels are planted and when the resultant seedlings are about one year old, they are selected on the appearance only. The cuttings of the selected ones are planted to definite areas. From this point on, the seedlings are tested several times for their sugar yielding power, with due consideration being given to other characters. Often, ratoon and two-year old crop are studied (3).

Ordinary technique used in bud-selection and seedling work. However, last season's experience with mud press cake as a germination medicine for (cane seed) gave unsatisfactory results (5).

*First Stage*: Large and small stools of cane showing definite characteristics of stooling and habit of growth are picked up from as many varied conditions on the plantation as can be found. No systematic "combing" of fields should be practised or too many similar types will be secured and make the elimination process too difficult.

*Second Stage*: All these stools are cut and planted in an area of fairly uniform soil, water and climatic conditions and allowed to grow to maturity. They should then be cut and allowed to ratoon. Notes should be made on these progenies from the time of planting and a continually close study made throughout the whole plant crop and ratoon. Such things as earliness of stooling and type of stooling should be particularly noted.

*Third Stage*: When the first ratoons are a year old—or if you are not in a hurry and allow the first ratoon to go to maturity too, in the second ratoon, cut out the progenies that have shown up as being different or outstanding. These should then be extended, each as if it were a new variety. Further extension should have no stool selection within the progeny but well nurtured seed should be used in all cases. Types that have been noticed in the original planting as being quite different growing alongside of each other, are usually planted again in adjoining blocks to note if these type differences continue.

*Fourth Stage*: When sufficient planting material is available a "checker-boarded" experiment should be laid out using unselected seed as a check. The harvesting data from such an experiment should be conclusive enough to determine whether any improvement has been made over the average of the variety.

The most important reform in our methods of breeding better varieties should be a detailed study of the characteristics, desirable and undesirable, that are hereditary in each of our main varieties; the purification of these characteristics and their combination by hand pollinization (5).

Greater stress is being laid upon seedling work here on this plantation, every effort being made to secure as many of the seedlings propagated and to develop seedlings here. Seedlings derived here, and others received from elsewhere, are planted first in a lower irrigated seed plot to secure as much seed as possible for the greatest spread when planted in regular test plots. The practice is to cut the seed in the lower seed plot and transfer

to the regular test plot, where each seedling is planted in such a way that it can be easily harvested and flumed to the mill for weighing and juice test. This necessitates planting the seedlings in sections 50 to 60 feet apart, for flumes here are placed from 50 to 75 feet apart, depending much upon the tonnage of the field. This method insures quicker results on a larger and more accurate scale, all scaling in the field on a small scale, and all juice tests from small quantities of the varieties and seedlings being eliminated. This method brings results in three years, one year in the seedling plot and two years at the test plot (12).

Our nursery methods in the seedling work have not changed materially in the past season and are described in last year's report. The problem of selecting the canes is very difficult, and requires the most thorough investigation. There are two points which we stress, viz: (1) to have all varieties planted adjacent to H 109 checks so that real comparisons can be made, (2) to place more reliance on the results secured from ratoons than plant cane. Our program calls for a monthly inspection of all seedlings and notes are made on their appearance on specially prepared cards. At harvest cane weights are secured and juice sampled. In selecting as our standard H 109, we have aimed very high. We grow many varieties that seem good, but few that actually come anywhere near the "he-cane," H 109 (7).

We use the same method in testing both types of progenies. After the progeny or seedling has been selected it is spread out into line or two line plots with H 109 as a check between each of the tests. These go through to maturity and are hand scaled and juice samples taken. Any that equal or outyield the H 109 check in sugar are spread as rapidly as possible into watercourses of level ditch area so that data on actual field conditions may be obtained. This covers a period of about four years; one and a half years after first selection, one year later cut for seed, and 18 months later cut for crop to get actual yield (9).

The factor which governs our selection is "tons of cane per acre." (See additional valuable data in original letter.) (11.)

In both the bud selection and the seedling work, trustworthy results may be obtained if regular variety tests are given to those that have survived very severe selection.

See tabulation of inheritance of color, etc., in Uba x D 1135 cross (11).

The following are supplementary answers to the questionnaire. William Wolters states:

Regarding the questionnaire on Genetics and its Relation to Cane Production, I beg to state that we have as yet not done very much in that line of work in view of the fact that this department only started to function about a year ago. Most of the time has been taken to establish this department and get it on a working basis before real investigations and research could be handled.

I am most willing, however, to extend whatever information regarding the above named subject that I possibly can. I will give you a resumé of what has been done along this line of work, and hope you may find something of interest, if not of value. I trust you will not be disappointed to find that your questionnaire is not answered as completely and satisfactorily as might be expected for reasons already given.

Practically no breeding work in cane has been done on the plantation as yet. Cane selection work has been done in a very small way and mostly in seedlings.

I. Seed pieces from a fair number of seedlings have been received from the Hawaiian Sugar Planters' Association Experiment Station and planted out in the fields. They are planted under normal conditions and receive plantation care in the way of fertilization, irrigation, cultivation, etc. Observations are made from time to time to note external characteristics, habits of growth and effects of environmental influences.

At about the time of maturity the first selection is made in which poor showing seedlings are eliminated. In this selection a large number are thrown out—fifty per cent or

more. The selected ones are planted out again using the best seed. Again these seedlings are planted under normal conditions and receive plantation treatment.

This process of selection goes on until we have seedlings which can reasonably stack up against our H 109 crop cane as a standard. It is not desirable to have seedlings that show no sign of merit or prospects of being a good commercial cane occupy valuable land.

We have reached the point where we have six seedlings that may show some promise of being a good commercial cane, but are not sure until we have tested them on larger areas and under varying conditions, and have assumed more or less fixed characteristics. The next logical step to take, therefore, would be to test them out on larger areas. So far we have these same seedlings growing on different parts of the plantation. In our case it is too early in the game to state any notable effects on seedlings as a result of change of location other than soil, in which case they grow better where the soil is richer.

II. In addition to seedlings grown from seed pieces, we have a patch of land set aside primarily to accommodate potted seedlings as bred by the Hawaiian Sugar Planters' Association Experiment Station, and planted by them in these pots.

A new lot was planted out the latter part of May, 1925. Here they were spaced two feet apart in 35-foot furrows and properly staked according to crosses in series. They received regular plantation care as usual. After a year's time the best will be selected and planted out and receive numbers, that is, Waipahu No. 1, etc. It is understood that seed pieces will be cut and planted. Selections will be made from time to time to eliminate the worst ones until we have a few which will, or may, show merit enough to compare favorably with H 109.

It is evident that the chief aim is to develop a cane, or canes, that may equal, or better, H 109, and supplant it in case anything may happen to H 109. Therefore this is the procedure which is being followed at the present time until some other procedure is deemed to be better.

No work in progeny studies has been done other than to plant out twenty-one H 109 progenies in one of our fields from selections by A. D. Shamel down at Waipio Sub-station. These will be studied from time to time to note anything which may be of interest and informing. It can clearly be seen that no information can be given at this time.

Our primary requirements for a cane here on the Oahu Sugar Company's plantation is one that will give a high yield, ratoon well, resist disease and also be capable of substituting a crop cane variety in case of necessity. Consequently any seedling which does not meet all these requirements in a fair proportion is not desired.

## By Y. Kutsunai:

I. (a) To obtain accurate data on the hereditary characters of the various varieties of cane used in seedling work for the purpose of combining desirable characters intelligently.

Characters sought are adaptability, heavy cane yields, good quality ratio, and high degree of resistance to diseases and injury.

(b) Selection is based on cane yield and the quality ratio. These two characters seem in general to be compensating. In case the cane is not weighed, the volume of the cane is judged. The weight and the volume are very closely correlated.

(c) Some of the hybrids have established improved lines to the extent that they are replacing the older varieties.

(d) 1. Rose Bamboo, Yellow Tip, Striped H 109, Striped Yellow Caledonias, Striped D 1135, White D 1135.

2. Do not know. More mutants were found in H 109 than in Yellow Caledonia, but this difference may depend on the relative amount of labor spent in looking for the mutants.

3. Do not know, but plant crop is preferred in selection work.

4. Do not know.

5. Do not know.

(e) 1. Progenies are given ample room to develop so that their relative capacities only become the limiting factor.

2. The data on bud selection are conflicting and need more time to decide this point.

3. The difficulty of detecting the invisible characters and the masking influence of the environment.

4. Detailed study of the cane plant with the view of establishing visible indices correlated with invisible characters may help in this.

II. (a) 1. Two methods—hand pollination and natural pollination.

2. Hand pollination is resorted to when natural pollination is not possible.

3. H 109, Lahaina, Striped Mexican, Tip Canes, and Yellow Caledonia are considered to be the most favorable stock.

4. Uba as female. D 1135 and H 109 as male.

5. No decision has been reached on this point. Usually, the seedlings of known parentage show more female characters than the male characters, and this preponderancy may be due to a certain amount of selfing and not due to the prepotency of the female cane.

6. No.

7. (1). Progressive selection. Have no faith in the cumulative effect of bud selection practiced for a short time, but do believe in the repetition of selection for obtaining accuracy.

(2). Mutations: Feel this is the most important, but no method has yet been devised by which economic mutations can be spotted.

(3). Volunteer seedlings are not advantageous because they may not have the combinations sought, and they are not found when wanted.

(4). Hybrids seem to have vigor of growth.

(5). Selfs are too weak for immediate commercial purposes. They are valuable for studying heredity.

(6). Hand pollination permits the crossing of varieties planted far apart, but the method can not be followed on large scale on account of the labor required.

III. (a) 1. Bud selection: Stools with many, uniform, vigorous sticks are selected, cut for seeds, and planted. The resulting crop is cut, weighed, and the juices are analyzed. The high-sugar yielders are selected for further trial. The selection is repeated until satisfactory results are obtained. Sometimes ratoon crops are tested.

Seedlings: The desirable tassels are planted, and when the resulting seedlings are about one year old, they are selected on the appearance only. The cuttings of the selected ones are planted to definite areas. From this point on, the seedlings are tested for several times for their sugar yielding power, with due consideration being given to other characters. Often, ratoons and two-year crop are studied.

2. In both the bud selection and the seedling work, trustworthy results may be obtained if regular variety tests are given to those that have survived very severe selection.

## By the agricultural department of the Experiment Station, H. S. P. A.:

I. (a) The ultimate object of all cane breeding is to find varieties which under certain conditions of environment will produce sugar with greater profit than the so-called "standard varieties" hitherto grown. This result is obtained by either increasing production per acre, or with hardier canes, producing sugar at less cost per unit.

These conditions of environment are somewhat as follows:

1. Climatic conditions.
   - Temperature (mean annual and extremes).
   - Rainfall.
   - Wind.
   - Sunlight.

2. Type of Soil.
   Drainage.
   Fertility.
   Toxic elements.
3. Rodents and Insect Pests.
4. Disease Organisms.
5. Weeds.
6. Plantation Practice.
   Cultivation.
   Fertilization.
   Irrigation.
   Length of crop.

Whether a seedling will produce sugar with greater profit than the former standard variety is determined by its degree of adaptability to any given set of conditions. A single change in these conditions may necessitate a different variety of cane.

With the above mentioned object in view the work of the cane breeder can be divided into three parts: (1) Selection of parent varieties, (2) nursery work of growing the seedlings from the tassels, (3) selecting the better seedlings from the undesirable, (4) determining the variety most suited to any given environment.

Seedling work is, of course, endless since perfection can never be attained, and conditions always change.

1. (b) Selection is based on sugar yield, other factors being secondary. (So far no other character has been found that can be correlated with sugar content except possibly vigor of growth.)

(c) Several hybrid seedlings have been grown at the Station, which show decided improvement over former standard varieties. H 109 is now planted in place of Lahaina on the lowlands, and several Tip and Uba seedlings have been developed that may take the place of D 1135 and Tip canes on the upper fields. H 109 itself will probably very soon be replaced by its own offspring or those of Lahaina.

With bud selection improved lines have not yet been definitely established.

(d) 1. So far the only certain mutations have been those of color. Examples are: Striped H 109, Striped D 1135, Striped U D 1. Rose Bamboo has been observed as a mutation of Striped Mexican.

2. No definite data, both seem to show color mutations.

3. Not sufficient data for conclusions to be drawn.

4. This has never been determined here, at least.

5. The only known mutations are those of color, and these have not been definitely correlated with high sugar yield.

(e) 1. Our progeny tests are conducted in such a manner as to avoid if possible varying environmental influences. The plot chosen for progeny work must be practically level and the soil as uniform as is possible with Hawaiian soils. Only such seed is planted as will give even germination, since a good stand is an essential. Germination is often further controlled by first planting the seed in temporary boxes with removable bottoms. The sides of the boxes are widest at the bottom and narrowest at the top, so that when the cane is finally planted in the ground the bottom is withdrawn, and the sides can be lifted from the plant without disturbing the root system. An attempt has been made to avoid unevenness of light, aeration, and water by placing the plants in rows five feet apart from center to center, and using flumes in place of the ordinary watercourses. The amount of water given each plant is checked as accurately as the scope of the experiment will allow. (At Makiki the flow of water is regulated by stop watch.) In the case of the fertilizer this can of course be accurately apportioned to each stool. Plants bordering on the outside of the plot would have the advantage of more light and space, therefore their yields are not considered.

2. It is too early to state definitely that bud selection has resulted in the establishment of improved strains. One of our Yellow Caledonia progenies seems to have made a

very good record, but it must undergo further tests before its value is determined positively. It was six or seven years after its propagation before the superiority of H 109 was proven with any degree of certainty. Perhaps the reason people are too quickly becoming discouraged with bud selection is that everyone was a little too optimistic at the beginning.

3. The greatest difficulties of the work in hand appear to be:

(1) Inability to recognize mutations other than those of color.

(2) Practically impossibility of absolutely controlling environment.

4. Our present method of planting the cane in holes spaced five feet apart is our latest attempt at controlling environment. We must, of course, continue our efforts along this line. A closer study of the cane plant with the purpose of correlating visible characteristics with high sugar yield should also be made.

II. (a) 1. Two methods: (1) Natural crosses in the field, (2) Hand pollination.

2. Hand pollination is practiced (1) when it is impossible to obtain natural crosses, (2) in order to have more definite knowledge of parentage.

3. H 1801 is outstanding as a variety from which to obtain numerous germinations, probably largely selfs. D 1135 is also worked freely both ways. H 109 has much less tendency to self. This also applies to the Tip canes, Striped Mexican, Lahaina and Badila. So in order to obtain field crosses of these with D 1135 it is better to use D 1135 as the male parent, as one gets less selfs in that way. (See appended chart.)

4. In the case of hand pollinated material definite statements can not be made. At the Station, Uba has been found to be a good female parent, but without more data on this point comparisons should not be made.

5. Badila and Yellow Caledonia as female parents seem to be prepotent for high sugar content and vigor of growth respectively. This subject has not been critically studied as yet.

6. Carefully planned out factorial analysis has not yet been attempted. In first generation Uba hybrids, the Uba characters predominate.

7. Seedling work has proven value. Bud selection has not advanced far enough to be compared with it. The ratio of their ages here is as 20 is to 5. As we see it, the two should go hand in hand. Seedling work to produce new varieties with new combinations of characters to meet varying conditions, and bud selection mainly to keep up what we already have to its original standard. Bud selection in sugar cane is not creating anything new. It is trying to purify what you already have.

III. 1. Every stool is carefully examined, and data is recorded as to disease, insect infestation and injury, rat damage, mechanical injury, etc. In some tests juice analyses are made. The number of stalks in each stool is noted, and their uniformity recorded. The stools are weighed and the heaviest in the higher yielding progenies are then selected for new progeny tests. From these heavy stools only the best seed is chosen, and planted in boxes. Those plants which seem to have germinated best are transferred to test plots, and planted in holes with even spacing. Those plants which were poor in germination are either discarded or used as protecting rows bordering the selected material.

The factor which governs our selections is "tons of cane per acre."

2. It is thought that by bringing in new varieties, such as Kassoer and the Java canes (now in quarantine), the scope of our seedling work can be broadened and the chances of obtaining desired crosses considerably increased. The idea being to produce hardy canes, thereby lowering cost of production.

There is also much to be done along the line of determining what characteristics are transmitted to their offspring by the different cane varieties. This will enable us to decide which parents will give the best crosses for any given set of environmental conditions.

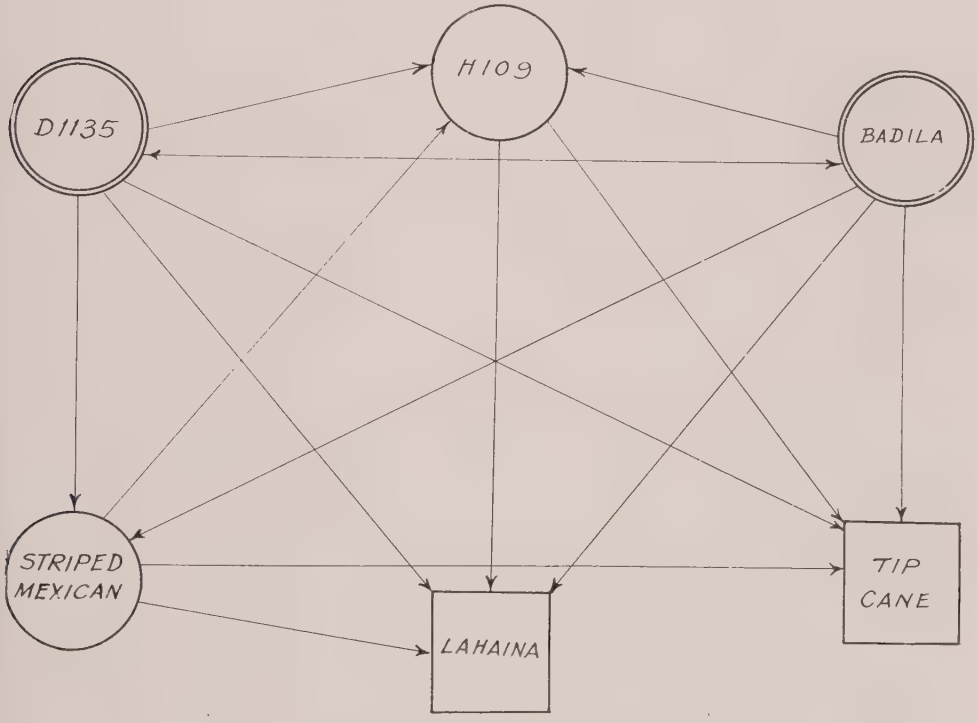
Lastly, the development of pure lines through inbreeding offers great possibilities for seedling work of the future.

## INHERITANCE OF VARIOUS CHARACTERS IN THE UBA X D 1135 HYBRIDS

The Uba x D 1135 hybrids seem for the most part to resemble the female parent, Uba, rather than D 1135. Any one at all familiar with the parents receives this impression after even a hasty inspection. It is, however, very difficult to put this impression down in the form of exact figures. The following data have been compiled from rather careful descriptions of the seedlings on file at the Station. The personal factor for such characters as color and hardiness of rind is rather too great to attach very much importance to this tabulation.

### DIAGRAM SHOWING DIRECTION OF POLLEN TRANSFER IN SUGAR CANE CROSSES

Arranged from data obtained in study of cane flowers and field observation of hybrid canes—Season 1924-1925




Double circle = Self fertile flowers. Circle = Slightly Self fertile flowers. Square = Self sterile flowers.

**Color.** In the case of color any hybrid with even a small amount of purple, red, pink, bronze or brown was thought to show a tendency toward D 1135. The others, which were colored green, gray green, yellow green, or yellow were classed as showing Uba characteristics.

| | |
|---|---|
| Uba coloring | 70 |
| D 1135 coloring | 41 |
| | 111 |

**Hardness of Rind.** The fact that Uba has considerably harder rind than D 1135 served to again classify the seedlings.

| | |
|---|---|
| Uba | 76 |
| D 1135 | 26 |
| Doubtful | 9 |
| | 111 |

**Eyes.** Uba eyes are prominently pointed, so much so that they generally pierce the leaf sheath. There is also a marked tendency to lala. D 1135, on the other hand, has flat, round eyes that seldom lala and never pierce the leaf sheath.

| | |
|---|---|
| Uba type eye | 49 |
| D 1135 | 47 |
| Combination | 10 |
| Unclassified | 5 |
| | 111 |

# A Select List of References on Genetics and Breeding of Plants and Animals*

By F. G. Krauss
Professor of Agronomy, The University of Hawaii

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# The Control of Irrigation Water*

(*Published in Abstract*)

By J. M. Watt

## The Purpose of Measurement

There may be several purposes for the measurement of the irrigation waters on plantations. When a definite policy of irrigation has been decided upon through observation and research, the measuring of water will be confined to the measurement of the supply, the measurement between sections, the measurement to the

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field, and ditch seepage losses from which the balance of the daily supply is obtained.

In the early stages of work, before the point is reached where a water balance is available, measurement has necessarily to be carried on along several other lines, and this is the stage of the work that most of the plantations are concerned with at the present time. These are for purposes of investigation and observation.

In the first place all waters coming onto the property ought to be measured in order to arrive at accurate cost figures relative to supplies.

The plantation is generally divided into sections under the jurisdiction of section overseers. Some of these sections require more or less water, depending on the nature of the soil, conditions of environment, nature of the fields, age of the cane, and other factors that may complicate the problem. This water should be carefully measured so that the right amount will go to the right place at the proper time. In this way difficulties due to shortages and oversupply may be avoided.

It is of importance to have measuring devices at the head of each field so that the section overseer can distribute his total supply in an intelligent manner. In this manner it is a very easy matter to know at any time exactly what has been taking place within the field from the time of the last harvest.

To arrive at the maximum duty of water so that a water balance may be created, it is necessary to carry on experiments to determine the response of the cane to treatments that are favorable or unfavorable. In this work, ditches within type fields should be selected and different treatments applied. By the variation of practices throughout these, the water requirement for a given treatment is available at the conclusion of the experiment. It is through measurements of this kind, carried on with measurements of total water applied to fields of varying types that the duty of water may be found. Then, by knowing what should be done, and also what has been done, which is only obtainable through records of field runs in the past, errors in judgment and practice can be detected, and proper methods applied. At such a time, and at no other time can an intelligent balance be applied.

Experiments of varying kinds are possible to determine the cane response to water application. The first of a series which has been carried on for the past two years is called the Regulated Irrigation Experiment; in this type of experiment several ditches are selected within fields of as many varying types and cropping systems as possible, enough ditches being selected to allow for practice repetitions if possible. In each ditch, preferably at the head or intake of the ditch, a measuring device should be installed to record water applied. Then the special practices are determined in an arbitrary manner at first as there has been nothing of the kind previously done upon which to base policies. A minimum treatment is scheduled in which the cane is irrigated at intervals which will in no way allow for an excess of irrigation. A normal treatment is then scheduled in which it is felt that the cane is irrigated at the best possible interval, and in the third or maximum treatment the intervals are so scheduled as to give the cane all the water that it can possibly use. Against these, check ditches are provided in which the irrigation follows the practice of the remainder of the field which is irri-

gated as the overseer gets to it in the course of his rounds. In each instance as nearly as possible the same amounts of water per man are applied to each plot per irrigation.

From the results of an experiment of this nature upon harvest the practice favorable to a given type of field is indicated. If the limits have been too drastic or too wasteful, these are either drawn in or extended as the case may be. The practices applied for each treatment are similar in each type of field.

A second series of experiments in which ditches and measuring devices are selected in the same manner is called the Winter Cane Growth Experiment. In this case, treatments or intervals of irrigation are varied in the winter or cold months alone, with constant irrigation intervals throughout the summer or good growing months when cane growth is at its best. This type of experiment will show the amount of water or irrigation interval that is preferable in winter to give the best growing conditions. It is a very easy matter to apply too much water in winter, and this experiment is aimed at such a practice.

A third series is called the Summer Cane Growth Experiment; the experiment is similar to the one last mentioned except that the winter interval is constant, the variation being in the summer interval to determine the best practice for summer growth in fields of varying types.

A fourth series is the Cane Ripening Experiment. It is a general practice on the plantations to take water off the cane sometime before harvest, depending on the nature of fields. In this experiment several ditches of a similar character are selected and the time that water is to be taken off is decided upon. Here the ditches are grouped, some being carried on to the period of final irrigation at the normal field rate, while others have the interval of irrigation extended gradually for about five months before the time of final irrigation. In this manner sucrose response and cane growth are observed in all ditches. The practice that gives the greatest sucrose content and lowest cane tonnage per acre is the one that is to be desired.

By carrying on experiments of this nature the best practices to follow can be determined and through a combination of these results the best general practice can be provided for. This will show the maximum duty of water in sugar production per acre, so that a definite water balance may be created and maintained throughout a given plantation.

Other experiments may be carried on to decide upon favorable practices such as the water requirement in hilling up as against non-hilling up with the resultant sugar yield, experiments determining the value of long line irrigation as against regular contour irrigation, various forms of plowing, various methods of applying water to the furrow, various lengths of watercourses and number of lines between ditches, or any number of other practices that may be tested.

It is only through work of this nature that we can obtain correct information, correct poor practice, and place irrigation on a sound basis. Fertilizer problems were gone at in this manner, and the same can be done with our water problems.

## Soil Moisture Determinations

The determination of soil moisture depends entirely on the nature of information that is desired.

The main value of this work is in studies of the retention capacities of soils, depth of percolation of water in soil types, or variation of the latter in soils of the same nature under varying conditions.

Soil moisture determination work is very laborious, expensive, takes a great deal of time, and the value of it ought to be very clearly estimated before it is gone into on a large scale.

## Cane Growth Measurements

The growth of cane is varied by a great many conditions. Taking measurements under these conditions enables keeping a continuous record of crop progress. These measurements can also be applied in general practice to get a comparison of cane growth from year to year over different or successive crops and cropping methods.

They are, however, of little or no value unless enough of them are taken to insure average figures, as variation within a field or plot of cane is known to be considerable.

In each plot or ditch at least five locations should be selected, and within each location no less than five sticks should be measured to insure relatively good average figures. Measurements of elongation should be accompanied by measurements of diameter, or preferably of circumference to obtain volumetric measurement to determine the total quantity of cane on the ground. For special work, more measurements may be taken over given plots. In general field work, five locations of five sticks each at least are necessary to enable drawing reasonably accurate conclusions.

Measurements should commence early in the life of a field to indicate every possible response or change of growing conditions. Measurement of growth may be started from two to three weeks after the cane is harvested in some instances and carried on to the time of maturity.

These measurements require an immense amount of work and the sheets upon which the data are collected rapidly become voluminous, so that it is a good policy to have the averages of growth and diameter systematically carried forward on filing cards where they may be studied.

Measurements of growth may be taken at periodic intervals or at given intervals of irrigation. In the latter the response in growth to a given application of water is readily obtained and has been found in many cases to be the best practice. This method is favored, although it takes a great deal more time.

These measurements may be taken to bring out several very interesting points such as periodic growth of cane, growth in relation to seasonal variation, growth in relationship to the age of the cane, and cumulative growth with varying experimental treatments applied.

Men should be selected for this work who are interested in it, diligent, and accurate, as it is tedious and hard work, especially when the cane is big and the stand heavy.

## Juice Sampling

Periodic sampling of cane juice prior to harvest is of value in many instances, as it will show the varying condition of cane in a field and often serve as a guide in taking off a field at the most advantageous point.

In experimental work, it is of great value as it allows a person to study the response of the sucrose content with respect to water treatments before the field is harvested. It can be carried on in conjunction with growth measurement work to show the correlation between growth water application and juice condition.

This work is not reliable unless a great many samples are taken; it is tedious and laborious work and requires most exacting efforts to be of value. Samples should be taken over many locations and where special influences do not affect the juice.

All such data as they become voluminous ought to be averaged and filed on cards for ready reference and study.

## Overhead Irrigation

Irrigation of sugar cane by means of the overhead application of water is a relatively new venture in the Hawaiian Islands.

The method was developed at Hawi Mill & Plantation Company by Mr. Hind, and is known as the Hind System of Overhead Irrigation. It has worked very well, and through the application of this system higher cane yields have been obtained than ever before upon the same lands.

The water is applied by the use of a number of sprinkler heads mounted on riser pipes at a height, and spaced at distances, depending on surrounding conditions. The water can be obtained from gravity flow, or it may be supplied from a pump that will give the required pressure for proper operation of the system. One method works as well as the other.

Before the installation of such a system it is advisable to lay out some experimental standpipes to determine the required pressure, the size of the pipes needed, the range of throw of the heads, particularly under varying wind conditions, as the spacing of other installations in general will not be a satisfactory guide.

By actual comparison with contour plots separated from the sprinkler areas by buffer plots so that one will not be affected by the other, it has been observed that the stand of the cane and appearance is equally good. Actual germination and stalk count after a period of six or eight months showed that the sprinkler plots were in the lead. The cane is as thick in one as in the other.

A three-inch application will penetrate the trash blanket of one-hundred-ton per acre cane and penetrate the soil to a depth of two or three feet, which shows that the system can be used with heavy cane.

Some of the main advantages of the system are that the soil or field is more easily prepared for planting; the expense of moldboarding is eliminated, as a shal-

low furrow is all that is required, a good soft seed bed for the cane to start in; the elimination of land required for watercourses and ditches as in contour irrigation; a great saving from the standpoint of labor required to produce cane; a uniform distribution of water throughout the area, absolute control of the water that is applied to the land; a good means of fire protection; and by better control of irrigation the sucrose content of the cane may be brought to a higher point through control of ripening. Irrigation can be carried on either by day or by night as desired.

Some of the disadvantages of the system may be the high cost of installation, difficulty in application of second season fertilizer when the cane is high, the possible rise in the salt content of the soil, and the increased growth of weeds in plant cane when the entire area is exposed to water. The real disadvantage of these points has not been proven to the point of condemnation.

### Summary of Replies Received in Answer to Questionnaire Sent Out in Connection With "Measurement and Control of Irrigation Water."

1. Eight plantations are measuring irrigation supplies received.

2. Sources of water. Artesian and mountain.

3. Standard rectangular weir with bottom and side contractions, and water stage recorder is most satisfactory method of measuring mountain water.

4. Water stage recorders used are Gurley and Stevens "E" and "L."

5. Pumped waters are measured by weirs at discharge end of pipe. Venturi meters at pumps, displacement, current meter measurements.

6. Measurements are used for distribution of costs over fields, determination of irrigation per acre and per man day, determination of seepage losses and duty of water.

7. Irrigation policy is controlled and water distributed according to field demands and irrigators available, using data to prevent waste and to encourage light applications.

8. Four plantations actually measure water as applied to land.

9. Advantage of field measurements—clear knowledge of field requirements, to determine duty of water and enabling creation of a water balance, knowledge of whether water is being used efficiently, determination of seepage losses.

10. Water required per acre per irrigation, man days required per acre, and water requirements of various soils in different seasons of the year are being determined by five plantations.

11. These measurements are, first, for the purpose of obtaining the maximum duty of the present supply of water, and, second, to determine what supplies should be developed to profitably irrigate areas now available.

12. The amount of water required to make a complete irrigation of each field is being measured by four plantations.

13. The object of this measurement is the creation of a water balance, through the determination of the duty of water for the various lands of a plantation, and to enable distributing water to the best advantage.

14. Duty of water experiments are now being conducted on five plantations.

15. These consist of regulated irrigation experiments, seasonal cane growth measurements, cane ripening experiments, and comparisons of different types of irrigations, to determine correlation of water, temperature and growth, the ultimate object being the maximum duty of water.

16. Actual growth measurement of growing cane is reported by seven plantations.

17. Soil moisture determinations are not of much value due to varying saturation within a given location (as, for example, the top and bottom lines of the same watercourse). They do, however, determine how far down irrigations are affecting soil moisture.

18. Juice sampling is carried on in all investigational areas on one plantation from seven to eight months before harvest to the actual harvesting of the field, to show change of condition of the cane.

19. The correlation between measured water, soil moisture content, juice condition prior to harvest, and growth measurements varies with locality or soil type, but is expected to be of the greatest assistance from a practical standpoint.

20. Eight plantations report that the division of water between sections of the plantations is facilitated by the proper measurement of water.

21. This enables making a more equitable distribution of the water available at the different sources; serves as a check on the efficiency of irrigation applications; and determines the variation with locality and soil type.

22. Measuring equipment used includes weirs, Great Western Meters (submerged orifice type), Gurley Stage Recorders, Stevens Stage Recorders, Gurley Current Meters, Venturi Meters, Reliance Meters, Watson Water Stage Recorders.

23. The policy of measurement of irrigation water is favored, as it is a true basis for reliable information regarding duty of water, a water balance, the proper and most useful distribution of supplies; the basis of determination of future needs, determination of amount of water each man can handle efficiently, and enables changes in practice which will increase yield and cheapen cost of production.

24. Plantations now carrying on this work intend to increase the scope—several others are inaugurating the work.

25. The Hind Overhead System—Opinion is that it appears to grow good cane, saves labor, allows positive irrigation in definite amounts with equal distribution of water, cuts down ditch seepage losses; is advantageous in irrigating young plant and young ratoons where light and more frequent irrigations are required.

Possible bad features are fertilizer applications to big cane, and initial cost of installation.

# Methods in Statistics*

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All of our measurements are subject to error, so we always have to decide what value to accept from a given set of measurements, and what degree of confidence to place in the accepted value. The method of resolving these doubts is based upon the theory of probability. The reasoning employed in establishing this theory is based upon the assumption that all the separate events in any number of them under consideration are equally likely to occur. In practice, of course, this assumption will not hold completely, as a rule, so care must be taken that data

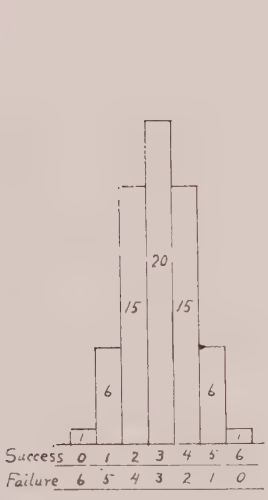



Fig. 1




Fig. 2

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analyzed are adequate in number, and so chosen as to be typical of the larger masses to which the conclusions are to be applied. To be more specific, when conclusions are to be drawn from the study of a sample, and then applied to the large collection from which the sample was drawn, it is of vital importance that the sample should contain enough individuals so that the variations within it are likely to be about the same as those within the original collection, and especially that the sample should be taken at random—that even an unconscious selection of any particular type of individuals should be avoided, if possible.

The rectangles of Fig. 2 form a "frequency distribution polygon," showing the results of 397 measurements, by several successive classes in mathematics, of a supposedly spherical slated globe. The measuring apparatus consisted of a good meter stick, graduated to millimeters, a pair of wooden compasses, with which a circle could be drawn upon the globe, then transferred to a blackboard, measured, and the diameter computed from the result. In the figure the heights, or, as the bases are the same, the areas, of the rectangles show the number of values of the variable which fell in the interval indicated at the bottom. The figure at the bottom of a rectangle (below OX) denotes the middle of the interval. Thus, the interval marked 45.54 cm includes all measurements that fell within the interval 45.52 cm to 45.56 cm, including the former, and excluding the latter. This rectangle has a height, or area, of 26 units, since 26 of the values fell within that interval. The values of the variable (diameter of the globe) ranged from about 45.20 cm to about 46.20 cm, as is shown on the scale below OX. This range of 1 cm, more than 2 per cent of the total diameter, might tend to rouse our suspicions, were it not that so few results fell near the extremes, about the same proportion at the upper extreme as at the lower, while the great mass of the results fell near the middle of the range. Finally, the most important consideration, there is no known reason, aside from this suspicion, for rejecting one measurement rather than another.

Without any theory to work upon, we might lean toward 45.68 as a good value to accept, since more than half of the area of the polygon, that is, more than half of the measurements, fall within six rectangles, three to the right, and three to the left of this value. This method, however, might not assign enough weight to the rest of the results, farther to the right and left. It might be better to find the point where an ordinate (line parallel to OY) would have to be erected to bisect the area of the polygon. This point on OX, or this value of the variable, is called the median. The total area of the frequency polygon is 397, so we are to find the position of an ordinate that would have an area of 198.5 units on each side. Turning to the data for Fig. 2, and summing the frequencies (column "f"), from the top down, we find that those down to 41 sum up 166. Adding the next one, 45, we have 211. As 198.5 lies between these sums, we see that the required ordinate passes through the rectangle whose base is 45.64 to 45.68, and whose area is 45 units. Deducting 166 from 198.5 we have 32 5, the area within this rectangle that must lie to the left of the median. This is 32.5/45 or 0.722 of the whole rectangle. As the base of the rectangle represents 0.04 cm, we multiply 0.04 by 0.722, which gives 0.029 cm. Adding this to 45.64, the left end of the base, we get 45.669 as the median value, or the point on OX where an ordinate would

have to be erected, to bisect the frequency polygon. As we shall find, for this set of measurements, this is very near the vertical axis, OY, which passes through the value of the arithmetic mean.

By exactly the same method, we find that the ordinate at 45.524 will bisect the left half of the polygon, and that one at 45.761 will bisect the right half. These points are called the quartile values. The space between these ordinates is one-half of the area of the frequency polygon, and the interval between them represents 0.237 cm, so the quartile values show us that one-half of our measurements fall within a range of 0.237 cm, thus throwing some light on the accuracy of our set of readings.

By reasoning that cannot be introduced here, the theory of probability has proved that the most probable value from a set of results like this is the arithmetic mean of the whole set. This would be obtained by summing up all the values, and dividing by the total number of measurements. But as several other rather involved computations have to be made from the same data, the work of all is greatly abbreviated by first throwing the data into a convenient number of equal classes. The size of the classes is determined by considerations depending upon the nature of the material in hand, but one precaution may be noted here: the classes should be large enough so that every one will have at least one item in it. Following are the data for Fig. 2, with a brief statement of the method of computation:

DATA FOR FIGURE 2

| m | f | d | v | fv | $fv^2$ | Probability Curve | |
|---|---|---|---|---|---|---|---|
| 45.22 | 1 | —0.48 | —12 | — 12 | 144 | x | y |
| .26 | 3 | —0.44 | —11 | — 33 | 363 | 0 | 38.23 |
| .30 | 4 | —0.40 | —10 | — 40 | 400 | 1 | 37.14 |
| .34 | 7 | —0.36 | — 9 | — 63 | 567 | 2 | 34.03 |
| .38 | 8 | —0.32 | — 8 | — 64 | 512 | 3 | 29.41 |
| .42 | 10 | —0.28 | — 7 | — 70 | 490 | 4 | 23.99 |
| .46 | 16 | —0.24 | — 6 | — 96 | 576 | 5 | 18.45 |
| .50 | 21 | —0.20 | — 5 | —105 | 525 | 6 | 13.39 |
| .54 | 26 | —0.16 | — 4 | —104 | 416 | 7 | 9.17 |
| .58 | 29 | —0.12 | — 3 | — 87 | 261 | 8 | 5.92 |
| .62 | 41 | —0.08 | — 2 | — 82 | 164 | 9 | 3.61 |
| .66 | 45 | —0.04 | — 1 | — 45 | 45 | 10 | 2.07 |
| .70 | 42 | 0.00 | 0 | 0 | 0 | 11 | 1.13 |
| .74 | 44 | 0.04 | 1 | 44 | 44 | 12 | 0.56 |
| .78 | 30 | 0.08 | 2 | 60 | 120 | 13 | 0.28 |
| .82 | 18 | 0.12 | 3 | 54 | 162 | | |
| .86 | 14 | 0.16 | 4 | 56 | 224 | | |
| .90 | 10 | 0.20 | 5 | 50 | 250 | | |
| .94 | 9 | 0.24 | 6 | 54 | 324 | | |
| .98 | 6 | 0.28 | 7 | 42 | 294 | | |
| 46.02 | 5 | 0.32 | 8 | 40 | 320 | | |
| .06 | 2 | 0.36 | 9 | 18 | 162 | | |
| .10 | 3 | 0.40 | 10 | 30 | 300 | | |
| .14 | 2 | 0.44 | 11 | 22 | 242 | | |
| .18 | 1 | 0.48 | 12 | 12 | 144 | | |
| | 397 | | | Neg. 801 | 7049 | | |
| | | | | Pos. 482 | | | |

The figures under **m** show the classes into which the measurements have been thrown: thus, class 45.58 includes all results from 45.56 to 45.60, including 45.56, and 29 measurements fell within that interval, as may be seen under **f**, that is, in the "frequency" column. Under **d** we have the deviation of each class under **m** from an assumed mean of 45.70 cm. Column **v** is obtained by dividing the corresponding items of column **d** by 0.04 cm; hence it shows, for instance, that class 46.06 has a deviation 9 times 0.04 cm from the assumed mean of 45.70. In practice, of course, it is not necessary to write column **d** at all. Simply write 0 opposite the assumed mean, —1, —2, —3, etc., in order above it, and 1, 2, 3, etc., in order below it. Column **fv** is obtained by multiplying items of column **f** by corresponding items of column **v**; it shows that the 2 measurements of class 46.06 have a total deviation of twice 9-times-0.04-cm, or 18 times 0.04 cm. The negative items in this column total 801, the positive items total 482, and the difference, negative 319, shows that the total deviation of the 397 measurements was negative 319 times 0.04 cm from the assumed mean of 45.70 cm. Multiplying 0.04 by 319, and dividing the product by 397, we get negative 0.032 cm as the average deviation, which deducted from 45.70 gives 45.668 cm, the mean of the 397 measurements. Column $\mathbf{fv}^2$ is obtained by multiplying items of column **fv** by corresponding items of column **v**. The sum, 7,049, is divided by 397, giving 17.76, the average of the squared deviations. As these are deviations from the assumed mean, the correction, 0.032 must be applied. It is first divided by 0.04 to reduce it to the same unit as the average. The result 0.8 of the class interval, is squared and deducted from 17.76 giving 17.12, a close approximation to the square of the deviations from the actual mean. The square root of 17.12 is 4.138, the "standard deviation." By the much more laborious method of obtaining **fv** and $\mathbf{fv}^2$ as deviations from the actual mean, the standard deviation turns out 4.143, showing that the approximation is very close. (The assumed mean must not differ greatly from the actual.) The smaller the standard deviation, the better the set of readings.

We must now seem to abandon the matter in hand for a while, in order to make clear what follows. That we may deal with events which are as nearly as possible equally likely to occur, let us suppose a coin tossed three times in succession, with the object of throwing as many heads as possible. Counting a head as a success, a tail as a failure, we see that three failures may fall out in just one way, that is, three failures in succession. So, also, three successes can occur in just one way. But two failures and one success can fall in three ways: (1) first toss a success, the rest failures, (2) second toss a success, the rest failures, (3) third toss a success, the rest failures. In the same way, two successes and one failure can occur in just three different ways. Thus we see that there are eight possible ways for the coin to fall, but only four possible combinations of success and failure. So the probability of three successes, or three failures, is one-eighth, that of two successes and one failure, or two failures and one success, is three-eighths. The sum of these four probabilities is 1, that is, one of these combinations is certain to happen. Fig. 1 is a graphic showing of the possibilities when a coin is tossed six times. The seven possible combinations of success and failure are tabulated in the two rows at the bottom. By reasoning exactly like

that given above, it can be shown that the coin may fall in 128 different ways, and that the distribution of the ways among the different combinations is 1, 6, 15, 20, 15, 6, 1, as graphically indicated by the areas of the vertical rectangles. Thus two successes and four failures may fall out in 15 of the 128 different ways, so the probability of that result is 15/128. Now if the same computations were made for 100,000 tosses, and the results plotted to the proper scale, we should have an apparently continuous curve, like the dotted one of Fig. 2, called the "probability curve."

The equation of this curve is $y = ae^{-kx^2}$, where **a** and **k** depend upon the values of the set under consideration. The method of deriving this equation is too difficult for insertion here, but an understanding of it is not necessary for the use of the equation. To find **a** for our curve, we multiply the standard deviation by 0.3989 and divide 397 by the product, giving 38.23. To find **k** we double the square of the standard deviation, and take the reciprocal of the result. For our curve we get $k = 0.02914$, so the equation of the probability curve for our set of determinations (showing the "normal distribution" of the results) is

$$y = 38.23e^{-0.02914x^2}$$

with the OY axis at the mean value, 45.668. Scale above OX gives x-values. To compute the quartiles, we multiply the standard deviation by 0.6745 which gives us 2.794. To get the equivalent in cm, we multiply this by 0.04, which gives 0.112 cm. That is, the quartiles are at that distance to the right and left of the mean, or at 45.78 and 45.556, respectively, thus differing slightly from the quartiles of the distribution polygon. The quartiles give us the probable error of a single reading; that is, the chance is even that a single reading will fall within 0.112 cm above or below the mean.

Dividing the quartile value 2.794, by the square root of 397, the total number of measurements, gives us 0.14, the probable error of the arithmetic mean. Its equivalent in cm is 0.0056, so we write the mean $45.668 \pm 0.006$. This does not mean that the true value lies between those limits, but that if another set of the same number of determinations were made, the chance is even that the mean of them would lie within those limits.

Let us now turn to the dotted curve of Fig. 2. If the number of readings for the various values had been according to the ordinates of this curve, the set would have had the same mean, with the same probability, as our original frequency polygon. Comparing polygon with curve, we see that the effect of the large number of values in the neighborhood of the mean has been neutralized, partly, by excesses at the extremes, and deficiencies near A, on the right, and to less degree elsewhere. If there had been a smaller proportion at the extremes, and a greater proportion near the mean, the curve would have been more steep and slender, the standard deviation and the quartiles would have been nearer the axis OY, the probable error of the mean would have been smaller. In short, it would have been a better set of readings. That is, *the steeper and more slender the curve, the better the set of readings.*

Let us suppose that the curve is the record of a large number of readings. Comparatively few of them fell near the value 45.20. The curve is concave upward from there to A, so we may infer that the number of readings for each

value increased, at an increasing rate, until A was reached. From A to the highest point the curve is concave downward, showing that the number of readings for each value increased, at a decreasing rate, throughout that interval. In the same way, the curve shows a decrease, at an increasing rate, from the highest point to A on the right, and a decrease, at a decreasing rate, from there on. The distance of A from OY is equal to the standard deviation.

DATA FOR SCATTER DIAGRAMS

| Fig. 6 | | Fig. 7 | | Fig. 8 | |
|---|---|---|---|---|---|
| X | Y | X | Y | X | Y |
| 1.24 | 51.0 | 1.41 | 9.57 | 1.44 | 10.48 |
| 1.36 | 51.1 | 1.24 | 8.41 | 1.67 | 7.79 |
| 1.45 | 55.2 | 1.53 | 10.38 | 1.45 | 10.33 |
| 1.67 | 53.4 | 1.45 | 9.84 | 1.53 | 9.28 |
| 1.51 | 56.8 | 1.74 | 11.81 | 1.36 | 11.75 |
| 1.31 | 54.8 | 1.31 | 8.89 | 1.31 | 12.66 |
| 1.45 | 55.2 | 1.52 | 10.31 | 1.49 | 9.79 |
| 1.39 | 54.8 | 1.29 | 8.75 | 1.71 | 7.43 |
| 1.52 | 53.8 | 1.45 | 9.84 | 1.41 | 10.93 |
| 1.41 | 54.6 | 1.87 | 12.69 | 1.33 | 12.28 |
| 1.29 | 49.0 | 1.57 | 10.65 | 1.31 | 12.66 |
| 1.49 | 51.8 | 1.41 | 9.57 | 1.52 | 9.40 |
| 1.45 | 51.8 | 1.51 | 10.25 | 1.66 | 7.89 |
| 1.42 | 55.3 | 1.33 | 9.02 | 1.42 | 10.77 |
| 1.31 | 51.2 | 1.31 | 8.89 | 1.57 | 8.81 |
| 1.57 | 62.4 | 1.42 | 9.63 | 1.31 | 12.66 |
| 1.44 | 52.4 | 1.66 | 11.26 | 1.24 | 14.13 |
| 1.41 | 51.2 | 1.39 | 9.43 | 1.51 | 9.53 |
| 1.31 | 48.5 | 1.45 | 9.84 | 1.87 | 6.21 |
| 1.33 | 51.8 | 1.31 | 8.89 | 1.45 | 10.33 |
| 1.87 | 61.4 | 1.36 | 9.23 | 1.74 | 7.18 |
| 1.66 | 58.8 | 1.71 | 11.60 | 1.45 | 10.33 |
| 1.53 | 55.4 | 1.67 | 11.33 | 1.29 | 13.06 |
| 1.74 | 59.6 | 1.49 | 10.11 | 1.41 | 10.93 |
| 1.71 | 66.0 | 1.44 | 9.77 | 1.39 | 11.25 |

Figs. 3 to 8 are intended to furnish simple illustrations of correlation between data. Turn first to the data for Fig. 7. Column X may be taken to represent the lengths of small bits of wire, column Y the corresponding weights. Fig. 7 is called a "scatter diagram" of these data. Numbers in the two top rows, increasing toward the right, indicate the classes into which the Y data have been thrown; those in the first two columns, increasing upward, the classes of the X-data. In making the diagram, we note that the first item in the X-column belongs in the 1.40 to 1.47 class, the corresponding Y-item in the 9.40 to 9.89 class, so we put a score mark even with the first class, and under the second. For the second item we put a score even with the first X-class, under the first Y-class, and so for all the others. In the end the score marks form a pretty fair diagonal of the rectangle, and we infer a pretty close correlation—the bits of wire were probably almost uniform in diameter.

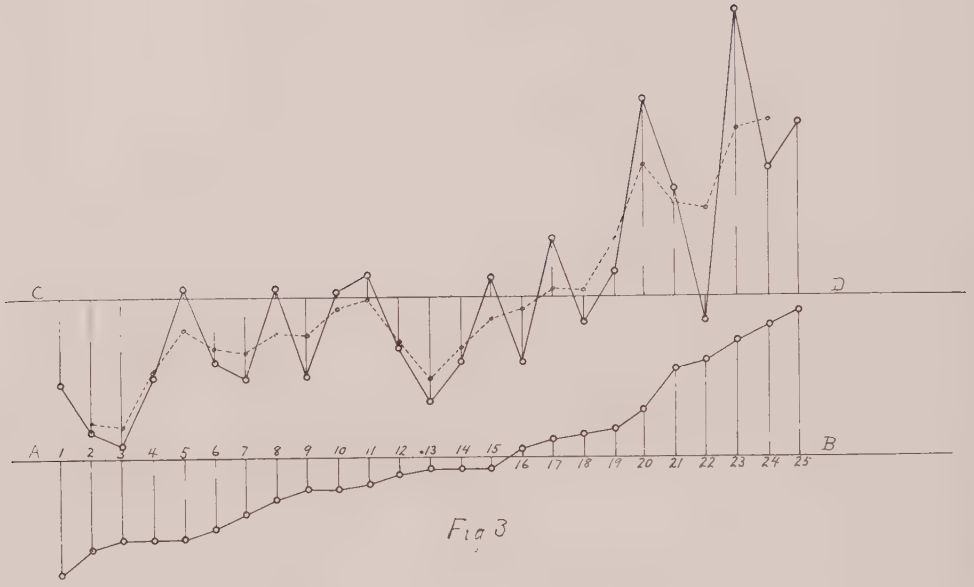

C
D
A
B
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Fig 3

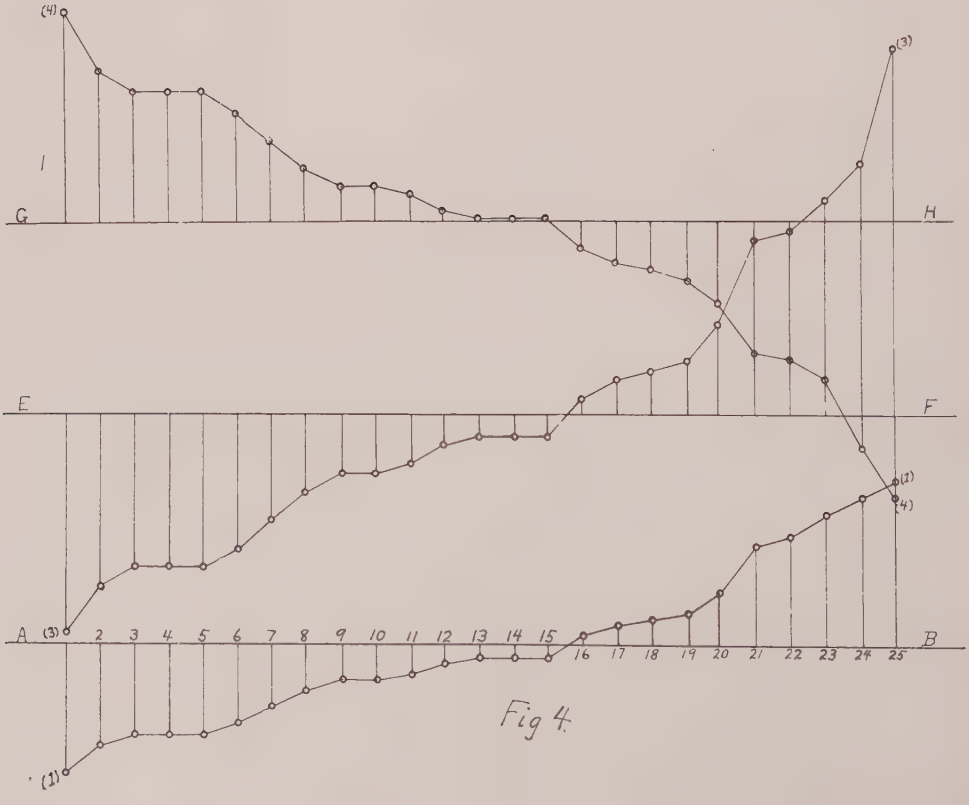

(4)
(3)
I
G
H
E
F
(1)
(4)
A
(3)
B
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
(1)

Fig 4.

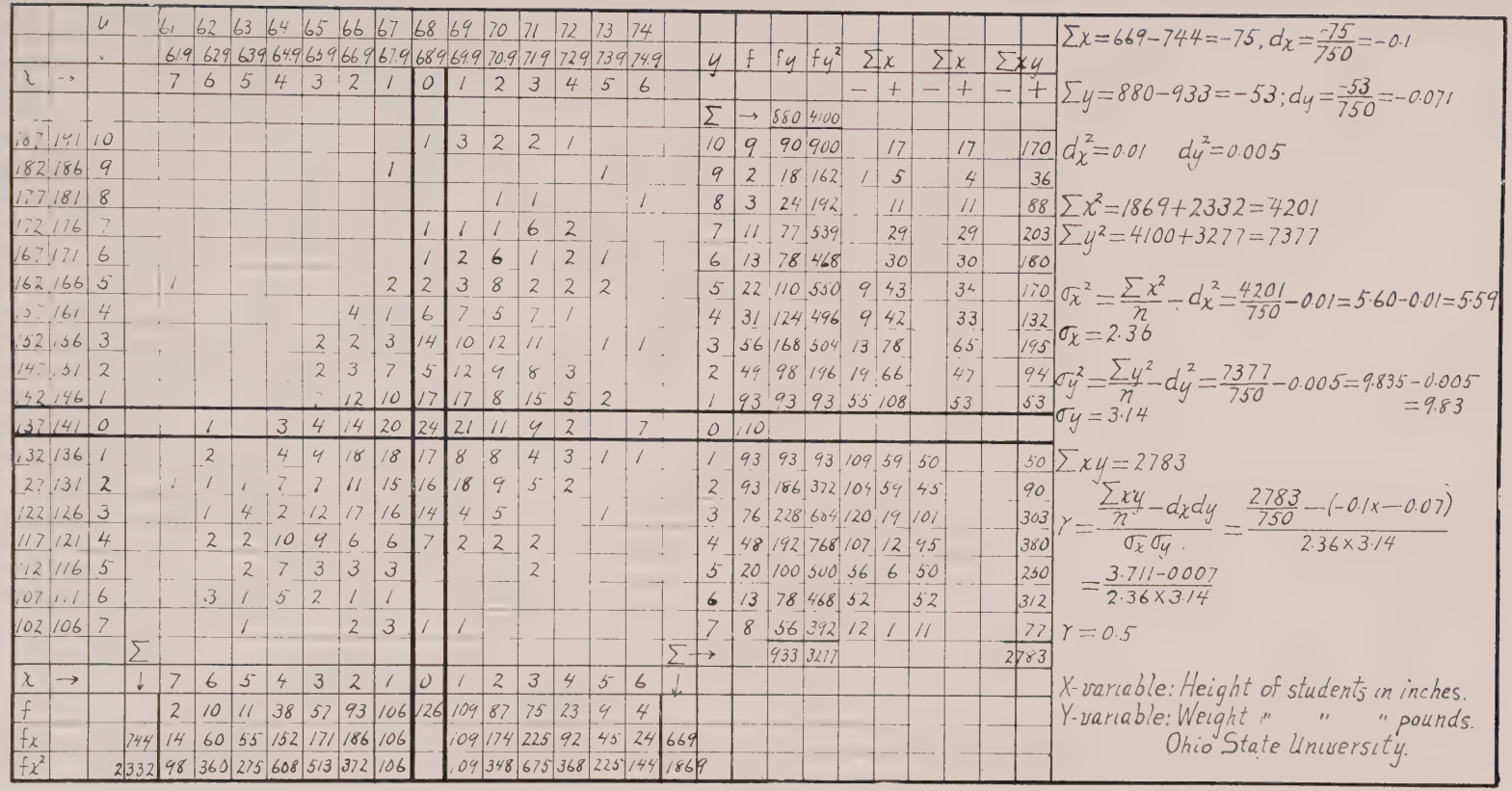

$\Sigma x = 669 - 744 = -75,\ d_x = \frac{-75}{750} = -0.1$
$\Sigma y = 880 - 933 = -53;\ d_y = \frac{-53}{750} = -0.071$
$d_x^2 = 0.01 \quad d_y^2 = 0.005$
$\Sigma x^2 = 1869 + 2332 = 4201$
$\Sigma y^2 = 4100 + 3277 = 7377$
$\sigma_x^2 = \frac{\Sigma x^2}{n} - d_x^2 = \frac{4201}{750} - 0.01 = 5.60 - 0.01 = 5.59$
$\sigma_x = 2.36$
$\sigma_y^2 = \frac{\Sigma y^2}{n} - d_y^2 = \frac{7377}{750} - 0.005 = 9.835 - 0.005 = 9.83$
$\sigma_y = 3.14$
$\Sigma xy = 2783$
$r = \frac{\frac{\Sigma xy}{n} - d_x d_y}{\sigma_x \sigma_y} = \frac{\frac{2783}{750} - (-0.1 \times -0.07)}{2.36 \times 3.14}$
$= \frac{3.711 - 0.007}{2.36 \times 3.14}$
$r = 0.5$
X-variable: Height of students in inches.
Y-variable: Weight " " " pounds.
Ohio State University.

Fig. 5

In the data for Fig. 8, column X may be taken to represent the length of various pendulums, column Y the corresponding number of beats in a given time. Plotted in a scatter diagram they give a close approximation to the downward diagonal of the rectangle, and we infer a rather close negative correlation—that is, an "inverse relation" between the length of a pendulum, and the number of beats in a given time.

Fig. 6 is the scatter diagram of the data for Fig. 3, and as the scores are rather scattered, but along the upward diagonal, we should infer an imperfect positive correlation. In Fig. 3, the same data are plotted, with the X-data arranged to increase toward the right, so that the curve never descends. The horizontal axis is not shown for either curve, the lines AB and CD representing the means of the X and Y curves, respectively. The general upward trend of the Y-curve indicates a certain amount of correlation, and the dotted curve through it, the result of "smoothing," shows it a little better. Each item of the original curve is averaged with the two items adjacent to it, to get the corresponding item of the smoothed curve.

DATA FOR FIGURE 3

| | X | Y | $d_x$ | $d_y$ | $d_x d_y$ | | $d_x^2$ | $d_y^2$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.24 | 51.0 | —0.234 | — 3.48 | +0.814 | —0.000 | 0.0548 | 12.1104 |
| 2 | 1.29 | 49.0 | —0.184 | — 5.48 | +1.008 | | 0.0339 | 30.0304 |
| 3 | 1.31 | 48.5 | —0.164 | — 5.98 | +0.981 | | 0.0269 | 35.7604 |
| 4 | 1.31 | 51.2 | —0.164 | — 3.28 | +0.538 | | 0.0269 | 10.7584 |
| 5 | 1.31 | 54.8 | —0.164 | + 0.32 | | —0.052 | 0.0269 | 0.1024 |
| 6 | 1.33 | 51.8 | —0.144 | — 2.68 | +0.386 | | 0.0287 | 7.1824 |
| 7 | 1.36 | 51.1 | —0.114 | — 3.38 | +0.385 | | 0.0130 | 11.4244 |
| 8 | 1.39 | 54.8 | —0.084 | + 0.32 | | —0.027 | 0.0071 | 0.1024 |
| 9 | 1.41 | 51.2 | —0.064 | — 3.28 | +0.210 | | 0.0041 | 10.7584 |
| 10 | 1.41 | 54.6 | —0.064 | + 0.12 | | —0.008 | 0.0041 | 0.0144 |
| 11 | 1.42 | 55.3 | —0.054 | + 0.82 | | —0.044 | 0.0029 | 0.6724 |
| 12 | 1.44 | 52.4 | —0.034 | — 2.08 | +0.071 | | 0.0012 | 4.3264 |
| 13 | 1.45 | 50.2 | —0.024 | — 4.28 | +0.103 | | 0.0006 | 18.3184 |
| 14 | 1.45 | 51.8 | —0.024 | — 2.68 | +0.064 | | 0.0006 | 7.1824 |
| 15 | 1.45 | 55.2 | —0.024 | + 0.72 | | —0.017 | 0.0006 | 0.5184 |
| 16 | 1.49 | 51.8 | +0.016 | — 2.68 | | —0.043 | 0.0003 | 7.1824 |
| 17 | 1.51 | 56.8 | +0.036 | + 2.32 | +0.084 | | 0.0013 | 5.3824 |
| 18 | 1.52 | 53.8 | +0.046 | — 0.68 | | —0.031 | 0.0021 | 0.4624 |
| 19 | 1.53 | 55.4 | +0.056 | + 0.92 | +0.052 | | 0.0031 | 0.8464 |
| 20 | 1.57 | 62.4 | +0.096 | + 7.92 | +0.760 | | 0.0092 | 62.7264 |
| 21 | 1.66 | 58.8 | +0.186 | + 4.32 | +0.804 | | 0.0346 | 18.6624 |
| 22 | 1.67 | 53.4 | +0.196 | — 1.08 | | —0.212 | 0.0384 | 1.1664 |
| 23 | 1.71 | 66.0 | +0.236 | +11.52 | +2.719 | | 0.0557 | 132.7102 |
| 24 | 1.74 | 59.6 | +0.266 | + 5.12 | +1.362 | | 0.0708 | 26.2144 |
| 25 | 1.87 | 61.4 | +0.396 | + 6.92 | +2.740 | | 0.1568 | 47.8864 |
| | 36.84 | 1361.9 | | | +13.081 | —0.434 | 0.5966 | 453.2060 |

In the table above are shown the computations for the "coefficient of correlation" for these same data. The column headed "$d_x$" contains the deviations of the X-values from the mean, that is, the lengths of the ordinates from AB to the

| | | 48.1 | 50.1 | 52.1 | 54.1 | 56.1 | 58.1 | 60.1 | 62.1 | 64.1 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 50. | 52. | 54. | 56. | 58. | 60. | 62. | 64. | 66. |
| 1.80 | 1.87 | | | | | | | / | | |
| 1.72 | 1.79 | | | | | | / | | | |
| 1.64 | 1.71 | | | / | | | / | | | / |
| 1.56 | 1.63 | | | | | | | | / | |
| 1.48 | 1.55 | | / | / | / | / | | | | |
| 1.40 | 1.47 | | /// | / | /// | | | | | |
| 1.32 | 1.39 | | // | | / | | | | | |
| 1.24 | 1.31 | // | // | | / | | | | | |

Fig. 6

curve, in Fig. 3. Column "$d_y$" contains the deviations of the Y-values, the lengths of the ordinates from CD to the curve. Column "$d_x d_y$" contains the products of the corresponding values in the "$d_x$" and "$d_y$" columns, part of them positive, part negative. The last two columns are the squares of the corresponding values in the "$d_x$" and "$d_y$" columns. These deviations have all been obtained by the longer method, finding the actual value of the mean, and then deducting it from the successive values of the frequencies. The work of substituting for the correlation coefficient is shortened, as we simply sum the last three columns, multiply together the sums of the last two, extract the square root, and divide the sum of the "$d_x d_y$" column by the square root. The shorter method is given in Fig. 5. The correlation coefficient for these data turns out $r = 0.770$. To find the probable error, subtract the square of **r** from 1, and divide the result by the square root of the number of measurements. The result is 0.020.

In Fig. 4 are shown plots of the data for Figs. 7 and 8. Curve (1) represents the X-data of both plots, curve (3) the Y-data of Fig. 7, curve (4) the Y-data of Fig. 8. It is apparent at a glance that the products "$d_x d_y$" of (1) and (3) would all be positive, while those of (1) and (4) would all be negative. For the former the correlation coefficient turns out to be 0.99984, with a probable error of 0.00004; for the latter it is $-0.9956$, with probable error 0.0018.

| | | 8.40 | 8.90 | 9.40 | 9.90 | 10.40 | 10.90 | 11.40 | 11.90 | 12.40 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 8.89 | 9.39 | 9.89 | 10.39 | 10.89 | 11.39 | 11.89 | 12.39 | 12.89 |
| 1.80 | 1.87 | | | | | | | | | 1 |
| 1.72 | 1.79 | | | | | | | 1 | | |
| 1.64 | 1.71 | | | | | | 11 | 1 | | |
| 1.56 | 1.63 | | | | | 1 | | | | |
| 1.48 | 1.55 | | | | 1111 | | | | | |
| 1.40 | 1.47 | | | 1111 | | | | | | |
| 1.32 | 1.39 | | 11 | 1 | | | | | | |
| 1.24 | 1.31 | 1111 | | | | | | | | |

Fig. 7

Fig. 5 is a correlation table, to exhibit the correlation, and compute the correlation coefficient, of the height of 750 individuals, compared with their weight. The data, the method of arrangement, and the method of computation, are from "The Fundamentals of Statistics," by L. L. Thurstone, an exceedingly clear presentation of exactly what it claims to present. The body of the table is exactly like a scatter diagram, except that the frequencies are expressed as numbers, instead of as groups of score marks. In fact, the first step in making a correlation table must be to make something in the nature of a scatter diagram. At the bottom of the table is a row labeled "f." Each number in it is the sum of all the frequencies in the column above. The column enclosed in heavy lines contains the mean of these "fs." In the same way, in the column at the right labeled "f" each number is the sum of all the frequencies in the same row, and the row enclosed in heavy lines contains the mean. The rows labelled "fx," "$fx^2$," "fy" and "$fy^2$" are computed just as the corresponding columns were in the data for Fig. 2. A word may be acceptable, however, as to the columns after the "fy" column. The capital sigma in each heading means "the sum of," so the first two columns give the sum of the **x's**, positive and negative. To see how they are computed, let us turn to row 1, above the mean. On the negative side are 7, 12 and 10. Multiplying each by the number above it in the X-row at the top, and taking the sum, we have negative 55, which we find in the negative column of the sum of the **x's**. On the positive side are 17, 8, 15, 5 and 2. Multi-

| | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 6.99 | 7.99 | 8.99 | 9.99 | 10.99 | 11.99 | 12.99 | 13.99 | 14.99 |
| 1.80 | 1.87 | 1 | | | | | | | | |
| 1.72 | 1.79 | | 1 | | | | | | | |
| 1.64 | 1.71 | | III | | | | | | | |
| 1.56 | 1.63 | | | 1 | | | | | | |
| 1.48 | 1.55 | | | | IIII | | | | | |
| 1.40 | 1.47 | | | | | HHII | | | | |
| 1.32 | 1.39 | | | | | | II | 1 | | |
| 1.24 | 1.31 | | | | | | | III | 1 | 1 |

Fig. 8

plying each of these by the number above it in the X-row, and taking the sum, we have 108, which we find in the positive column of the sum of the **x's**. The sum of these two results is positive 53, which we find in the second positive column of the sum of the **x's**. Multiplying this by positive 1, the corresponding item in the Y's, we have positive 53, in the column of the sum of the **xy's**. Below the mean, we have negative items in the sum of the **x's**, but they are multiplied by negative values in the Y-column, thus giving positive values for the sum of the **xy's**.

At the extreme right is a detailed statement of the computation for the coefficient of correlation **r**. The character occurring twice in the denominator of the formula for **r** is the small sigma, and is always used as the symbol for the standard deviation. The two factors in that denominator are the standard deviation for the **x's** and the standard deviation for the **y's**. If **r** equals 1, we infer perfect positive, or direct, correlation. If **r** equals —1, we infer perfect negative, or inverse, correlation. The value of **r** must fall between these limits.

TABLE NO. 1

VARIETIES OF CANE

| | H 109 | Y. C. | D 1135 | Lahaina | Yellow Tip | Striped Mexican | Striped Tip | Rose Bamboo | Others |
|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co. | 94 | .. | 1 | 1 | .. | 3 | .. | .. | 1 |
| Oahu | 83 | .. | 16 | .. | .. | .. | .. | .. | 1 |
| Ewa | 100 | .. | .. | .. | .. | .. | .. | .. | .. |
| Waialua | 46 | 14 | 14 | 6 | .. | .. | .. | 3 | 17 |
| Pioneer | 63 | .. | 6 | 3 | 1 | 24 | .. | .. | 3 |
| Olaa | .. | 88 | 11 | .. | .. | .. | .. | .. | 1 |
| Haw. Sug. | 60 | 3 | 31 | .. | .. | .. | .. | .. | 6 |
| Maui Agr. | 65 | .. | 1 | 21 | .. | 7 | .. | 4 | 2 |
| Lihue | 37 | 55 | 2 | .. | 1 | .. | .. | .. | 5 |
| Onomea | .. | 87 | 2 | .. | 11 | .. | .. | .. | .. |
| Hilo | .. | 96 | 3 | .. | .. | .. | 1 | .. | .. |
| Kekaha | 39 | .. | 13 | 44 | .. | .. | .. | .. | 4 |
| Honolulu | 75 | 20 | 4 | .. | .. | .. | .. | .. | 1 |
| Haw. Agr. | .. | 47 | 20 | .. | .. | .. | .. | .. | 33 |
| Hakalau | .. | 93 | .. | .. | 6 | .. | .. | .. | 1 |
| Wailuku | 63 | 1 | 4 | 16 | .. | 14 | .. | .. | 2 |
| Makee | 32 | 62 | .. | .. | 2 | .. | .. | .. | 4 |
| McBryde | 50 | 42 | 5 | .. | .. | .. | .. | .. | 3 |
| Honokaa | 4 | 4 | 82 | .. | 3 | .. | 3 | .. | 4 |
| Laupahoehoe | .. | 47 | 9 | .. | 43 | .. | .. | .. | 1 |
| Pepeekeo | .. | 98 | 1 | .. | .. | .. | .. | .. | 1 |
| Hamakua | .. | 51 | 31 | .. | 11 | .. | .. | .. | 7 |
| Kahuku | 71 | 23 | .. | 6 | .. | .. | .. | .. | .. |
| Paauhau | 6 | 12 | 75 | .. | 6 | .. | .. | .. | 1 |
| Honomu | .. | 97 | .. | .. | 1 | .. | .. | .. | 2 |
| Koloa | 40 | 48 | 5 | .. | 1 | .. | .. | .. | 6 |
| Hutchinson | .. | 54 | 6 | .. | .. | .. | .. | 40 | .. |
| Waiakea | .. | 98 | 1 | .. | 1 | .. | .. | .. | .. |
| Hawi | 13 | 1 | 27 | .. | 2 | 2 | 54 | .. | 1 |
| Kaiwiki | .. | 36 | 9 | .. | 15 | .. | 7 | .. | 33* |
| Waianae | 99 | .. | .. | .. | .. | .. | .. | .. | 1 |
| Kohala | .. | 20 | 42 | .. | 13 | .. | 22 | .. | 3 |
| Kilauea | 20 | 22 | 9 | .. | 26 | .. | 1 | .. | 22† |
| Kaeleku | .. | 100 | .. | .. | .. | .. | .. | .. | .. |
| Waimanalo | 50 | 39 | 10 | .. | .. | .. | .. | .. | 1 |
| Union Mill. | .. | 3 | 24 | .. | 22 | .. | 49 | .. | 2 |
| Halawa | .. | 27 | 6 | .. | .. | .. | 67 | .. | .. |
| Waimea | 81 | .. | .. | 19 | .. | .. | .. | .. | .. |
| Olowalu | 74 | .. | .. | 1 | .. | 25 | .. | .. | .. |
| Niulii | .. | 35 | 8 | .. | 15 | .. | 42 | .. | .. |
| True Average 1925. | 42.7 | 30.8 | 11.9 | 3.1 | 2.7 | 2.0 | 2.0 | 1.0 | 3.8 |
| " " 1924. | 38.1 | 32.6 | 12.0 | 4.4 | 2.3 | 2.5 | 2.0 | 1.4 | 4.7 |
| " " 1923. | 30.7 | 36.3 | 11.2 | 8.4 | 1.2 | 3.1 | 1.6 | 1.5 | 6.0 |
| " " 1922. | 21.1 | 40.3 | 12.2 | 12.0 | 2.7 | 2.8 | 1.6 | 1.6 | 5.7 |
| " " 1921. | 15.0 | 45.1 | 11.0 | 17.4 | 1.2 | 3.0 | 1.8 | 1.0 | 4.5 |
| " " 1920. | 9.1 | 42.7 | 10.0 | 26.7 | 1.4 | 2.5 | 2.1 | 0.8 | 4.7 |
| " " 1919. | 6.8 | 46.4 | 7.2 | 29.1 | 0.3 | 1.8 | 2.6 | 2.1 | 3.7 |
| " " 1918. | 4.0 | 42.9 | 7.5 | 37.9 | 0.5 | 0.6 | 1.5 | 1.1 | 4.0 |

* Principally D 117.

† Principally Badila.

# Annual Synopsis of Mill Data—1925

By W. R. McAllep

Reports have again been received from all plantations in the Association covering manufacturing operations from October 1, 1924, to September 30, 1925, during which time 776,196 tons of sugar were manufactured. This calendar year does not in all cases coincide with the crop year. Figures from four plantations, Haw. Agr., Hutchinson, Paauhau and Kilauea, represent portions of the previous crop ground subsequent to October 1, 1924. These four plantations and two others, Waianae and Honokaa, had not finished grinding on September 30, so data for the 1925 crop of these plantations are incomplete. Appropriate marks identify data from these plantations in the large table.

Data are presented in the same form as last year except that two of the tables, apparent boiling house recovery and molasses produced on the theoretical, have been combined. Factories are again listed in the order of the average size of the crop for the preceding five years, except in Tables IV and VIII.

More complete data transmitted to the Experiment Station for the revised mill reports have facilitated the compilation of this Synopsis. Errors in the schedules have been detected that otherwise would not have been noticed and less correspondence relating to errors and discrepancies has been necessary. While compilation of data has been facilitated, analysis of data and drawing conclusions on the basis of comparison with previous years has been more difficult and less satisfactory, partly because of a change in the method of determining sucrose in final molasses, but principally on account of the disturbing effect of averaging figures for the Petree process with figures for the usual process. These discrepancies were discussed in the 1923 Synopsis and need not be repeated here. As the same proportion of the crop, 16 per cent, was manufactured in Petree process factories, both in 1924 and 1925, averages for these two seasons except those influenced by molasses purity may be compared directly. Table III, containing averages for the past four years for factories that do not use the Petree process, has been included again. It is becoming impracticable, however, to make at all close comparisons of averages affected by the Petree process, such as extraction, recovery, clarification results and filter press work, with corresponding averages for years prior to 1924 and but few such comparisons have been attempted.

## Varieties of Cane

Cane varieties making up 1 per cent or more of the total crop have been classed as major varieties and listed in Table I. Eight varieties, the same number as last year, are included in this classification. Yellow Caledonia and D 1135 are the most widely distributed, each of these varieties making up 1 per cent or more of the crop of thirty-one plantations. H 109, reported from twenty-three

TABLE NO. 2

COMPOSITION OF CANE BY ISLANDS

| | Hawaii | Maui | Oahu | Kauai | Whole Group |
|---|---|---|---|---|---|
| 1916 | | | | | |
| Polarization | 12.54 | 14.62 | 13.74 | 13.26 | 13.45 |
| Per cent Fiber | 13.22 | 12.22 | 12.51 | 12.86 | 12.74 |
| Purity 1st Expressed Juice | 87.56 | 89.41 | 87.15 | 86.26 | 87.70 |
| Quality Ratio | ..... | ..... | ..... | ..... | 8.22 |
| 1917 | | | | | |
| Polarization | 13.31 | 15.43 | 13.55 | 13.13 | 13.76 |
| Per cent Fiber | 13.23 | 11.67 | 12.25 | 12.89 | 12.62 |
| Purity 1st Expressed Juice | 88.11 | 90.40 | 86.77 | 86.70 | 88.02 |
| Quality Ratio | 8.21 | 7.03 | 8.20 | 8.27 | 7.95 |
| 1918 | | | | | |
| Polarization | 11.88 | 14.25 | 13.50 | 12.54 | 12.97 |
| Per cent Fiber | 13.35 | 11.53 | 12.23 | 12.84 | 12.50 |
| Purity 1st Expressed Juice | 87.27 | 88.62 | 86.93 | 85.88 | 87.18 |
| Quality Ratio | 9.27 | 7.73 | 8.27 | 8.60 | 8.47 |
| 1919 | | | | | |
| Polarization | 12.74 | 15.12 | 14.24 | 13.52 | 13.74 |
| Per cent Fiber | 13.07 | 11.74 | 12.14 | 12.61 | 12.49 |
| Purity 1st Expressed Juice | 87.54 | 88.81 | 87.00 | 85.82 | 87.34 |
| Quality Ratio | 8.66 | 7.25 | 7.81 | 8.20 | 8.05 |
| 1920 | | | | | |
| Polarization | 12.86 | 15.29 | 13.75 | 13.07 | 13.64 |
| Per cent Fiber | 13.36 | 11.39 | 12.65 | 12.72 | 12.64 |
| Purity 1st Expressed Juice | 87.87 | 88.94 | 85.40 | 86.52 | 87.24 |
| Quality Ratio | 8.45 | 7.08 | 8.07 | 8.28 | 8.00 |
| 1921 | | | | | |
| Polarization | 12.25 | 14.67 | 13.72 | 12.67 | 13.12 |
| Per cent Fiber | 13.28 | 11.82 | 12.40 | 13.28 | 12.80 |
| Purity 1st Expressed Juice | 87.18 | 87.37 | 85.46 | 84.07 | 86.22 |
| Quality Ratio | 8.98 | 7.51 | 8.11 | 8.76 | 8.41 |
| 1922 | | | | | |
| Polarization | 12.07 | 13.95 | 13.61 | 13.03 | 12.97 |
| Per cent Fiber | 13.16 | 12.38 | 12.88 | 13.22 | 12.95 |
| Purity 1st Expressed Juice | 87.17 | 87.88 | 86.18 | 85.80 | 86.84 |
| Quality Ratio | 9.19 | 7.75 | 8.04 | 8.36 | 8.45 |
| 1923 | | | | | |
| Polarization | 12.09 | 13.61 | 12.99 | 12.94 | 12.78 |
| Per cent Fiber | 13.14 | 12.01 | 12.86 | 12.99 | 12.82 |
| Purity 1st Expressed Juice | 87.61 | 88.65 | 85.52 | 86.58 | 87.05 |
| Quality Ratio | 9.12 | 7.91 | 8.50 | 8.42 | 8.57 |
| 1924 | | | | | |
| Polarization | 12.44 | 14.34 | 13.48 | 13.34 | 13.26 |
| Per cent Fiber | 12.99 | 12.16 | 12.72 | 12.94 | 12.74 |
| Purity 1st Expressed Juice | 87.98 | 89.19 | 87.02 | 87.31 | 87.86 |
| Quality Ratio | 8.86 | 7.58 | 8.16 | 8.12 | 8.25 |
| 1925 | | | | | |
| Polarization | 12.35 | 14.42 | 13.52 | 13.24 | 13.22 |
| Per cent Fiber | 12.92 | 12.40 | 12.60 | 12.91 | 12.74 |
| Purity 1st Expressed Juice | 88.02 | 89.36 | 87.11 | 87.19 | 87.92 |
| Quality Ratio | 8.92 | 7.47 | 8.18 | 8.21 | 8.28 |

plantations, is third, and Yellow Tip, reported from eighteen plantations, is fourth in distribution. Nine plantations only ground Lahaina this season against twelve in 1924 and fifteen in 1923.

H 109, while third in distribution, is first in tonnage ground, having materially increased its lead. Yellow Tip is now in fifth place, having displaced Striped Mexican. This is the only change in the ranking of the major varieties, though Yellow Tip will probably displace Lahaina from fourth place in another year.

Increased proportions of but two major varieties, H 109 and Yellow Tip, were ground. The proportion of Yellow Caledonia, Lahaina, Striped Mexican and Rose Bamboo decreased materially. The latter will probably be classed among the minor varieties in another season or two.

Varieties making up 1 per cent or more of the crop of any one plantation but less than 1 per cent of the total crop, are classed as minor varieties. These are shown in the following tabulation. Minor varieties listed in the 1924 Synopsis are also given for convenient comparison:

| Variety | Per cent of total crop | |
|---|---|---|
| | 1924 | 1925 |
| D 117 | .49 | .52 |
| Badila | .46 | .35 |
| H 146 | .51 | .26 |
| Yellow Bamboo | .02 | .14 |
| Uba | .03 | .11 |
| H 456 | ... | .11 |
| H 20 | ... | .10 |
| White Bamboo | .11 | .06 |
| H 227 | ... | .05 |
| Total | 1.62 | 1.70 |

H 456 is in this classification for the first time. This variety made up more than 1 per cent of the crop at two plantations, Makee and McBryde, and was also reported from a third plantation, Kilauea.

## Quality of Cane

Table II contains data on quality of cane for the whole group and by islands for the last ten years. This season the cane was slightly poorer than in 1924. Fiber was identical in both seasons. Slightly higher juice purity this year was more than offset by lower polarization, resulting in a quality ratio of 8.28 against 8.25 in 1924.

Changes since last year in the quality of cane on individual islands are small, the largest being an improvement of from 7.58 to 7.47 in quality ratio on Maui. The cane was of poorer quality on Hawaii and Kauai. On Oahu the quality differs but slightly from last year. Oahu figures show an apparent discrepancy. Both juice purity and cane polarization are slightly higher, yet the quality ratio increased from 8.16 to 8.18. The apparent discrepancy is due to an increase of 0.5 in Java ratio, or ratio of cane polarization to first expressed juice polarization.

TABLE NO. 3.

True Averages of All Factories Except Those Now Using the Petree Process.

| | 1922 | 1923 | 1924 | 1925 |
|---|---|---|---|---|
| Cane— | | | | |
| Polarization | 12.77 | 12.66 | 13.08 | 12.99 |
| Fiber | 13.03 | 12.91 | 12.82 | 12.80 |
| Tons per ton sugar | 8.76 | 8.68 | 8.40 | 8.45 |
| Bagasse— | | | | |
| Polarization | 1.71 | 1.53 | 1.52 | 1.54 |
| Moisture | 41.31 | 41.29 | 41.26 | 41.25 |
| Fiber | 56.23 | 56.48 | 56.74 | 56.55 |
| Polarization per cent cane | 0.40 | 0.35 | 0.34 | 0.35 |
| Polarization per cent polarization of cane | 3.11 | 2.76 | 2.63 | 2.69 |
| Milling loss | 3.05 | 2.71 | 2.68 | 2.73 |
| Weight per cent cane | 23.16 | 22.84 | 22.59 | 22.63 |
| First Expressed Juice— | | | | |
| Brix | 18.23 | 17.99 | 18.34 | 18.14 |
| Polarization | 15.79 | 15.61 | 16.07 | 15.91 |
| Purity | 86.58 | 86.77 | 87.61 | 87.67 |
| "Java ratio" | 80.9 | 81.1 | 81.4 | 81.7 |
| Mixed Juice— | | | | |
| Brix | 13.26 | 13.11 | 13.37 | 13.44 |
| Polarization | 11.07 | 11.00 | 11.31 | 11.38 |
| Purity | 83.50 | 83.87 | 84.56 | 84.67 |
| Weight per cent cane | 111.65 | 111.95 | 112.66 | 111.03 |
| Polarization per cent cane | 12.38 | 12.31 | 12.74 | 12.64 |
| Extraction | 96.89 | 97.24 | 97.37 | 97.31 |
| Extraction ratio | 0.24 | 0.21 | 0.21 | 0.21 |
| Last Expressed Juice— | | | | |
| Polarization | 1.96 | 1.73 | 1.84 | 1.90 |
| Purity | 68.66 | 68.48 | 71.73 | 69.63 |
| Maceration per cent cane | 34.99 | 34.79 | 35.30 | 33.66 |
| Syrup— | | | | |
| Brix | 63.11 | 63.33 | 63.18 | 63.63 |
| Purity | 84.81 | 85.40 | 86.02 | 85.95 |
| Increase in purity | 1.31 | 1.53 | 1.46 | 1.28 |
| Press Cake— | | | | |
| Polarization | 1.96 | 2.20 | 2.16 | 2.17 |
| Weight per cent cane | 2.49 | 2.45 | 2.45 | 2.45 |
| Polarization per cent cane | 0.05 | 0.05 | 0.05 | 0.05 |
| Polarization per cent polarization of cane | 0.38 | 0.43 | 0.40 | 0.41 |
| Lime used per cent cane | 0.081 | 0.085 | 0.086 | 0.078 |
| Commercial Sugar— | | | | |
| Polarization | 96.88 | 96.88 | 97.20 | 97.23 |
| Moisture | 0.85 | 0.80 | 0.73 | 0.74 |
| Weight per cent cane | 11.41 | 11.53 | 11.91 | 11.83 |
| Polarization per cent cane | 11.06 | 11.17 | 11.58 | 11.50 |
| Polarization per cent polarization of cane | 86.94 | 88.37 | 88.76 | 88.78 |
| Polarization per cent polarization of juice | 89.69 | 90.86 | 91.16 | 91.24 |
| Final Molasses— | | | | |
| Weight per cent cane | 3.14 | 2.96 | 2.83 | 2.82 |
| Sucrose per cent cane | 1.07 | 0.99 | 0.97 | 0.93 |
| Sucrose per cent polarization of cane | 8.33 | 7.79 | 7.45 | 7.20 |
| Sucrose per cent polarization of juice | 8.60 | 8.01 | 7.65 | 7.40 |
| Gravity solids | 87.94 | 88.54 | 89.08 | 90.09 |
| Gravity purity | 38.60 | 37.68 | 37.81 | 36.97 |
| Undetermined Losses— | | | | |
| Polarization per cent cane | 0.21 | 0.11 | 0.14 | 0.16 |
| Polarization per cent polarization of cane | 1.28 | 0.65 | 0.76 | 0.92 |

Quality ratio is calculated from the first expressed juice analysis. The polarization of the latter decreased sufficiently to more than offset the increase in purity and thus give a higher figure for quality ratio.

Juice purities were higher than in the preceding season on Maui, Hawaii and Oahu, but were lower on Kauai. The average first expressed juice purity was the highest in eight years.

For several years fiber in the cane has consistently decreased on Hawaii, where fiber is usually the highest, and has increased on Maui where the fiber is usually lowest. While in former years fiber content on different islands sometimes differed by as much as 1.5 per cent or 2 per cent, the maximum difference this season is but .5 per cent.

## Chemical Control and Sucrose Balances

A new method for determining sucrose in final molasses has been used this season. Sucrose determinations by the old method were somewhat too high, due to the influence of the lead precipitate. This error is avoided in the new method, the figure obtained more nearly approximating the true sucrose content. The average gravity purity this year is 37.32 against 38.16 in 1924. The difference is partly due to the change in method. Just how much cannot be stated definitely, particularly as in some instances the old method was used early in the season. On the basis of present information, the writer estimates that approximately a half of the difference is due to lower sucrose figures obtained with the new method.

The juice entering the boiling house is now weighed at all except four factories. Molasses is weighed at twenty-five factories and measured at ten, while at five factories it is neither weighed nor measured. Seven factories have failed to report the amount of molasses produced, rendering the figures for molasses less complete than in any year since 1920.

Twenty-seven factories have reported results on a sucrose basis this year, an increase of two. Gravity solids and sucrose balances for these factories are in Table V. One factory reports a negative undetermined sucrose loss. On a polarization basis, the basis used in compiling the large table, with good factory work a small negative undetermined loss is possible, but on a true sucrose basis negative undetermined losses can be attributed only to errors in control.

Apparent boiling house recoveries and molasses produced on theoretical are in Table VI. True boiling house recoveries are in Table VII. These tables are principally checks on the accuracy of the chemical control, though low figures are equally indicative of losses.

Deficiencies in control methods depressing the calculated figure for available below what it should be were discussed in the 1924 Synopsis. In the last few years, following changes in clarification practice, an increased number of factories have reported recoveries on available exceeding 100 per cent. This is the case this year with almost a half of the factories listed in Table VI and over a third of the factories listed in Table VII. While it is probable that slightly over 100 per cent recovery on the calculated available can be secured with good factory

TABLE NO. 4—MILLING RESULTS.

Showing the Rank of the Factories on the Basis of Milling Loss.

| | Factory | Milling Loss | Extraction Ratio | Extraction | Equipment |
|---|---|---|---|---|---|
| 1. | Hakalau | 1.08 | 0.09 | 98.93 | 2RC54,12RM9-60,3-66 |
| 2. | Waimanalo | 1.12 | 0.09 | 98.73 | K,3RC54,9RM54 |
| 3. | Onomea | 1.18 | 0.10 | 98.73 | 2RC60,S54,12RM66 |
| 4. | Hilo | 1.43 | 0.12 | 98.39 | K,2RC60,12RM66 |
| 5. | Olowalu | 1.82 | 0.14 | 98.17 | K,3RC48,9RM48 |
| 6. | Kekaha | 1.83 | 0.13 | 98.36 | 2RC54,15RM60 |
| 7. | Honomu | 1.94 | 0.15 | 98.15 | 3RC60,9RM60 |
| 8. | Wailuku | 1.95 | 0.14 | 98.37 | K,2RC72,12RM78 |
| 9. | Pepeekeo | 2.00 | 0.16 | 98.10 | 2RC54,9RM60 |
| 10. | Paauhau | 2.23 | 0.19 | 97.57 | 2RC60,12RM66 |
| 11. | Ewa | 2.28 | 0.17 | 97.99 | K(2),2RC78,18RM78 |
| 12. | Lihue | 2.40 | 0.19 | 97.59 | K,2RC78,S72,12RM78 |
| 13. | Kilauea | 2.57 | 0.22 | 97.11 | K,S,3RC60,9RM60 |
| 14. | Koloa | 2.68 | 0.22 | 96.84 | K,2RC60,12RM66 |
| 15. | Kahuku | 2.69 | 0.23 | 96.71 | K,2RC60,S54,9RM72 |
| 16. | Pioneer | 2.77 | 0.20 | 97.38 | K,2RC72,S72,15RM72 |
| 17. | McBryde | 2.78 | 0.20 | 97.21 | K,2RC72,S72,9RM84 |
| 18. | Haw. Sug. | 2.83 | 0.19 | 97.75 | K,2RC72,S72,12RM78 |
| 19. | Laupahoehoe | 2.85 | 0.22 | 97.04 | K,2RC54,9RM60 |
| 20. | Waialua | 2.93 | 0.21 | 97.25 | K(2),2RC78,12RM78 |
| 21. | Honolulu | 3.01 | 0.22 | 97.35 | K(2),S54,2RC78,9RM78 |
| 22. | Hamakua | 3.04 | 0.23 | 96.67 | K,2RC60,12RM60 |
| 23. | Oahu | 3.07 | 0.22 | 97.29 | K(2),2RC78(2),S72(2),12RM78(2) |
| 24. | Olaa | 3.11 | 0.24 | 96.90 | K,S72,12RM78 |
| 25. | Waianae | 3.11 | 0.22 | 96.73 | K(2),12RM60 |
| 26. | Makee | 3.16 | 0.25 | 96.60 | K,2RC72,S72,9RM72 |
| 27. | Haw. Agr. | 3.24 | 0.26 | 96.72 | 3RC60,12RM66 |
| 28. | Waimea | 3.29 | 0.25 | 96.89 | 2RC48,12RM42 |
| 29. | Kohala | 3.35 | 0.27 | 96.64 | K(2),3RC60,9RM60 |
| 30. | H. C. & S. Co. | 3.37 | 0.23 | 97.23 | K(4),2RC78(2),S72(2),12RM78(2) |
| 31. | Maui Agr. | 3.46 | 0.23 | 97.22 | K(2),3RC66,18RM66 |
| 32. | Kaiwiki | 3.68 | 0.29 | 96.05 | K,2RC60,9RM60 |
| 33. | Hawi | 3.80 | 0.30 | 96.26 | K(2),3RC48,12RM3 48,9-54 |
| 34. | Hutchinson | 3.94 | 0.32 | 96.42 | 2RC60,9RM60 |
| 35. | Waiakea | 4.11 | 0.33 | 95.31 | K,2RC60,9RM60 |
| 36. | Honokaa | 4.16 | 0.37 | 95.31 | K(2),2RC66,12RM66 |
| 37. | Kaeleku | 4.20 | 0.35 | 95.05 | K,2RC54,9RM60 |
| 38. | Union Mill | 4.28 | 0.36 | 94.91 | K,9RM60 |
| 39. | Halawa | 5.15 | 0.45 | 93.80 | K,2RC60,6RM50 |
| 40. | Niulii | 7.24 | 0.66 | 90.29 | K,9RM54 |

work, the writer considers recoveries of over 101 per cent on a true sucrose basis (Table VII) strongly indicative of errors in weights or analyses, or that excessive deductions have been made for suspended solids in mixed juice or for press washings returned to the mill. Three factories listed in Table VII show over 101 per cent recovery on the calculated available.

Figures for molasses produced on the theoretical in Table VI continue to show wide variations, though from year to year the tendency has been toward more consistent figures. As in previous years, the theoretical amount of solids in molasses has been assumed to be gravity solids in the syrup less solids accounted for in commercial sugar. Less than the theoretical amount of molasses, as thus calculated, should be actually produced for reasons discussed in previous Synopses. The average reported for the preceding four seasons was 88.8 per cent, a figure identical with the average for this year. If we assume that a range of five points above and below this average includes all reasonably accurate figures, this tabulation indicates the probability of losses or errors in control at ten factories.

## Extra Fuel

As would be expected, with the increase in grinding rate, a reduced amount of extra fuel has been burned. The reduction amounts to between 8 and 9 per cent.

## Milling

Bagasse moisture has decreased .02 but bagasse polarization has increased an equal amount, thus increasing the milling loss from 2.78 to 2.82 and decreasing the extraction from 97.33 to 97.29.

Averages for tons of cane ground per hour, tonnage ratio and pressure per foot of roller for the past few seasons are tabulated below:

| Year | Tons cane per hour | Tonnage ratio | Tons pressure per linear foot of roller |
|---|---|---|---|
| 1920 | 39.34 | .... | .... |
| 1921 | 36.58 | 1.40 | .... |
| 1922 | 39.93 | 1.54 | 65.2 |
| 1923 | 42.03 | 1.56 | 66.2 |
| 1924 | 43.63 | 1.62 | 66.9 |
| 1925 | 45.31 | 1.71 | 66.5 |

The increase in grinding rate over 1924 is 1.68 tons of cane per hour, equivalent to 4 per cent. In comparison with 1921 when the grinding rate was the lowest in recent years, the increase is 24 per cent. Operating at higher capacity has been quite general, twenty-eight factories reporting increases against ten reporting decreases. All decreases were small, in but three or four instances exceeding .05 in tonnage ratio and in no case exceeding .1. The increase in grinding rate has been through operating existing equipment at higher capacities, no additional milling equipment having been installed.

TABLE NO. 5
GRAVITY SOLIDS AND SUCROSE BALANCES

| Factory | GRAVITY SOLIDS PER 100 GRAVITY SOLIDS IN MIXED JUICE | | | | SUCROSE PER 100 SUCROSE IN MIXED JUICE | | | |
|---|---|---|---|---|---|---|---|---|
| | Press Cake | Commercial Sugar | Final Molasses | Undetermined | Press Cake | Commercial Sugar | Final Molasses | Undetermined |
| H. C. & S. C. | 2.5 | 84.2 | 12.0 | 1.3 | 0.5 | 94.4 | 5.2 | —0.1 |
| Oahu | 2.9 | 79.8 | 14.7 | 2.6 | 0.5 | 92.2 | 6.5 | 0.8 |
| Ewa | 5.4 | 76.5 | 16.7 | 1.4 | 0.4 | 90.9 | 7.2 | 1.5 |
| Waialua | 3.6 | 77.2 | 15.8 | 3.4 | 0.5 | 90.5 | 7.2 | 1.8 |
| Pioneer | 4.3 | 77.8 | 15.8 | 2.1 | 0.4 | 91.3 | 6.8 | 1.5 |
| Haw. Sug | 5.3 | 79.7 | 15.1 | —0.1 | 0.4 | 93.1 | 6.4 | 0.1 |
| Maui Agr. | 0 | 82.1 | 17.9 | 0 | 0 | 91.4 | 8.1 | 0.5 |
| Lihue | 3.0 | 75.5 | 18.2 | 3.3 | 0.3 | 90.2 | 7.9 | 1.6 |
| Onomea | 4.9 | 78.7 | 15.4 | 1.0 | 0.1 | 92.6 | 6.7 | 0.6 |
| Hilo | 4.2 | 77.9 | 16.0 | 1.9 | 0.3 | 92.3 | 7.2 | 0.2 |
| Haw. Agr. | 3.4 | 76.3 | 15.0 | 5.3 | 0.3 | 87.7 | 6.7 | 5.3 |
| Hakalau | 3.6 | 79.0 | 15.2 | 2.2 | 0.1 | 93.0 | 6.5 | 0.4 |
| Wailuku | 4.1 | 78.8 | 15.7 | 1.4 | 0.5 | 91.8 | 7.2 | 0.5 |
| Makee | 3.6 | 74.8 | 19.2 | 2.4 | 0.4 | 88.9 | 9.1 | 1.6 |
| McBryde | 4.4 | 77.7 | 17.6 | 0.3 | 0.2 | 91.1 | 7.8 | 0.9 |
| Honokaa | 5.8 | 75.6 | 17.2 | 1.4 | 0.4 | 91.1 | 7.9 | 0.6 |
| Laupahoehoe | 4.1 | 79.1 | 13.5 | 3.3 | 0.2 | 91.9 | 6.3 | 1.6 |
| Pepeekeo | 4.0 | 78.5 | 15.0 | 2.5 | 0.2 | 92.9 | 6.0 | 0.9 |
| Hamakua | 0 | 81.4 | 17.1 | 1.5 | 0 | 90.8 | 8.3 | 0.9 |
| Kahuku | 5.4 | 74.5 | 18.5 | 1.6 | 0.3 | 91.8 | 7.5 | 0.4 |
| Paauhau | 4.6 | 77.5 | 16.3 | 1.6 | 0.1 | 91.8 | 7.2 | 0.9 |
| Honomu | 5.4 | 77.5 | 16.2 | 0.9 | 0.3 | 91.8 | 7.0 | 0.9 |
| Koloa | 5.3 | 73.7 | 17.4 | 3.6 | 0.7 | 89.8 | 7.9 | 1.6 |
| Hutchinson | 4.1 | 75.6 | 17.1 | 3.2 | 0.6 | 88.9 | 8.5 | 2.0 |
| Waiakea | 3.2 | 76.8 | 16.4 | 3.6 | 0.7 | 89.6 | 7.8 | 1.9 |
| Kilauea | 4.2 | 69.8 | 21.7 | 4.3 | 1.2 | 86.2 | 10.2 | 2.4 |
| Waimanalo | 3.9 | 73.6 | 19.4 | 3.1 | 0.5 | 89.8 | 9.0 | 0.7 |

Pressure per foot of roller has been reduced 0.4 tons below the 1924 figure, though it was higher than in the previous two years for which averages are available.

Maceration has been reduced from 34.90 to 33.66 per cent. The amount of water added per hour is approximately the same as in 1924. Twenty-four factories report reduced maceration against sixteen reporting increases. From data discussed under "Evaporation," it would seem that evaporator capacity was sufficient to have brought the syrup to a fair density with the same amount of maceration as in 1924. It is quite probable that getting the extra quantity of cane through the mill as well as evaporator capacity has been a factor influencing the reduction in maceration.

It seems of interest to note the trend of changes in maceration practice during the seventeen years in which the figures for maceration have been averaged. Starting with 27.12 per cent in 1909, the amount was increased quite consistently until 40.80 per cent was used in 1919. Since then the tendency has been toward decreased maceration, the 33.63 per cent applied this year being but 82 per cent of the maximum in 1919 and the smallest amount since 1913. This means that maceration has been reduced to the amount applied before Messchaert grooves were introduced. In 1914, with maceration closely approximating the amount used during the past season, extraction was but 95.46.

The reported surface speed of the rollers increased slightly; some 4 per cent for two-roller crushers and 1 per cent for three-roller mills.

Mill settings were slightly wider. Attempting to reduce the change to a percentage basis is not entirely satisfactory, yet after carefully examining available data the writer believes that the following average figures are approximately correct: 15 per cent increase in crusher settings and from 2 to 2.5 per cent increase in mill settings. The proportionate increase in actual openings while grinding would be considerably less than the above figures on account of roller rise, slack, etc.

Comparatively few changes have been made in surface grooving. Coarse grooved rollers have been installed in first mills in one or two instances, but with this exception the changes reported show no definite tendency either toward coarser or finer grooving.

No changes of any consequence have been made in juice grooving.

Examination of data from individual factories indicates reduction in pressure and maceration as the factors principally responsible for the somewhat poorer milling results this year. Wider openings also appear to have adversely influenced extraction in some instances.

A very satisfactory feature of the milling work this year is the smaller difference in purity between first expressed and mixed juice. This has decreased from 2.81 to 2.72. The improvement is also reflected by an increase in Java ratio from 81.55 to 81.64. Lower extraction has tended to reduce the difference in juice purities but the effect of this year's small decrease in extraction is probably negligible. The principal factors affecting it are field trash on the cane and sanitation at the mill. No data definitely indicating the amount of field trash are available. We do know that considerable attention is being given to prevent-

## TABLE NO. 6

### APPARENT BOILING-HOUSE RECOVERY

Comparing per cent available sucrose in the syrup (calculated by formula) with per cent polarization actually obtained

| Factory | Available* | Obtained | Recovery on Available | Molasses Produced on Theoretical |
|---|---|---|---|---|
| H. C. & S. Co. | 93.55 | 95.69 | 102.3 | 90.2 |
| Oahu | 92.12 | 92.68† | 100.6 | 85.1 |
| Ewa | 92.63 | 92.25 | 99.6 | 93.9 |
| Waialua | 91.50 | 91.71 | 100.2 | 83.4 |
| Pioneer | 92.37 | 92.42 | 100.1 | 87.8 |
| Olaa | 91.88 | 90.81 | 98.8 | 95.7 |
| Haw. Sugar | 93.67 | 93.46† | 99.8 | 100.4 |
| Maui Agr. | 91.88 | 91.45† | 99.5 | 100.2 |
| Lihue | 90.69 | 91.26 | 100.6 | 85.8 |
| Onomea | 93.21 | 92.98 | 99.8 | 93.8 |
| Hilo | 91.64 | 92.67 | 101.1 | 88.4 |
| Kekaha | 90.69 | 90.79 | 100.1 | 89.4 |
| Haw. Agr. | 92.49 | 88.68 | 95.9 | 73.3 |
| Hakalau | 92.31 | 93.18 | 100.9 | 87.0 |
| Wailuku | 91.91 | 92.74 | 100.9 | 92.3 |
| Makee | 89.90 | 89.93 | 100.0 | 89.3 |
| McBryde | 92.41 | 91.90 | 99.4 | 98.9 |
| Honokaa | 91.30 | 91.80 | 100.5 | 91.6 |
| Laupahoehoe | 92.39 | 91.86 | 99.4 | 78.7 |
| Pepeekeo | 92.98 | 93.59 | 100.7 | 86.0 |
| Hamakua | 91.27 | 91.15 | 99.9 | 92.0 |
| Kahuku | 91.41 | 93.11 | 101.9 | 92.1 |
| Paauhau | 92.27 | 92.08 | 99.8 | 91.0 |
| Honomu | 92.74 | 92.61 | 99.9 | 95.5 |
| Koloa | 90.35 | 91.09 | 100.8 | 83.7 |
| Hutchinson | 90.62 | 89.56 | 98.8 | 85.9 |
| Waiakea | 90.88 | 90.76 | 99.9 | 83.4 |
| Hawi | 92.23 | 86.91 | 94.2 | .... |
| Kaiwiki | 91.61 | 91.57 | 100.0 | 88.8 |
| Waianae | 88.24 | 85.22 | 96.6 | .... |
| Kohala | 92.40 | 92.04 | 99.6 | 92.9 |
| Kilauea | 88.27 | 87.83 | 99.5 | 86.3 |
| Kaeleku | 90.06 | 91.47 | 101.6 | 82.0 |
| Waimanalo | 89.37 | 90.74 | 101.5 | 88.2 |
| Union Mill | 90.36 | 90.11 | 99.7 | .... |
| Halawa | 90.04 | 90.26 | 100.2 | .... |
| Waimea | 91.60 | 90.11 | 98.4 | .... |
| Olowalu | 88.77 | 84.55 | 95.2 | 78.2 |
| Niulii | 88.15 | 86.47 | 98.1 | .... |

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When the moisture in the sugar has not been reported 1 per cent has been taken. 38 has been used when the gravity purity of the molasses has not been reported.

† Sucrose.

ing sour accumulations around mills, juice strainers, etc., and judging from observations during factory inspections, sanitary conditions around milling plants are better than in former years. To the extent that improvement in mixed juice purity is due either to reduced amounts of trash or better mill sanitation, it reflects a saving of sugar that otherwise would be lost. Starting with a first expressed juice purity .06 higher than in 1924, the reduction of .09 in the decrease from first expressed to mixed juice purity has resulted in a mixed juice purity .15 higher than last year.

Factories are listed in the order of the size of the milling loss in Table IV. This table shows fewer large changes in relative standing than in recent years. Factories with improved standing amounting to five points or more are Kilauea (19 to 13), Koloa (22 to 14), Laupahoehoe (29 to 19), and Waialua (30 to 20). Factories that have dropped five points or more in relative standing are Pioneer (11 to 16), Hamakua (12 to 22), Makee (15 to 26), Haw. Agr. (20 to 27), Hutchinson (24 to 34), and Honokaa (27 to 36).

The first ten factories in Table IV last year are again the first ten this year with but little change in relative order except that Olowalu has advanced from ninth to fifth place. 98 extraction or better was secured at nine factories, equalling the maximum number in any previous year. Milling loss was reduced to less than 2.0 at eight factories; seven was the maximum number in any previous year. Hakalau has made a new record in milling loss reporting 1.08 for the season. Hakalau and Onomea shared the previous record in milling loss, both reporting 1.09 in 1923.

## Boiling House Work

*Clarification:* Results in clarification have been decidedly unsatisfactory, a .20 smaller increase in purity from mixed juice to syrup offsetting the benefits that should have been realized from higher initial purities and reducing the syrup purity to .05 lower than last year. Had the increase in purity been as large as last year the syrup purity would have been 86.47, which is higher than in any year since 1915. Such a result should have improved recovery by some .15, and additional benefits should have been secured through reduced inversion losses.

The average for increase in purity in the large table, at its face value, is the lowest on record. While directly comparable with the corresponding figure for the previous season, it is not directly comparable with figures for seasons prior to 1924 because of discrepancies in the averages caused by including figures for the Petree process. So far as can be inferred from available data, the actual increase in purity this year was better than in 1921 but poorer than any other year for which we have a record.

The average for increase in purity in Table III for factories that do not use the Petree process is smaller than in the other three years for which separate averages from these factories are available.

A close estimate of increases in purity in Petree process clarification cannot be made for mixed juice figures are not available and comparisons with the first expressed juice purity, the only value that can be used as a basis for comparison,

TABLE NO. 7

TRUE BOILING-HOUSE RECOVERY

Comparing per cent sucrose available and recovered

| Factory | Available | Obtained | % Recovery on Available |
|---|---|---|---|
| H. C. & S. Co. | 93.79 | 94.87 | 101.2 |
| Oahu | 92.12 | 92.66 | 100.6 |
| Ewa | 92.65 | 91.27 | 98.5 |
| Waialua | 91.35 | 90.96 | 99.6 |
| Pioneer | 92.54 | 91.67 | 99.1 |
| Haw. Sug. | 93.67 | 93.47 | 99.8 |
| Maui Agr. | 91.88 | 91.44 | 99.5 |
| Lihue | 90.79 | 90.47 | 99.6 |
| Onomea | 92.97 | 92.69 | 99.7 |
| Hilo | 91.43 | 92.58 | 101.3 |
| Haw. Agr. | 92.77 | 87.96 | 94.8 |
| Hakalau | 92.23 | 93.09 | 100.9 |
| Wailuku | 91.96 | 92.26 | 100.3 |
| Makee | 90.00 | 89.26 | 99.2 |
| McBryde | 92.57 | 91.28 | 98.6 |
| Honokaa | 91.26 | 91.47 | 100.2 |
| Laupahoehoe | 92.16 | 92.08 | 99.9 |
| Pepeekeo | 93.02 | 93.09 | 100.1 |
| Hamakua | 91.13 | 90.78 | 99.6 |
| Kahuku | 91.65 | 92.08 | 100.5 |
| Paauhau | 92.15 | 91.89 | 99.7 |
| Honomu | 92.81 | 92.08 | 99.2 |
| Koloa | 90.31 | 90.43 | 100.1 |
| Hutchinson | 90.23 | 89.44 | 99.1 |
| Waiakea | 90.59 | 90.23 | 99.6 |
| Kilauea | 87.87 | 87.25 | 99.3 |
| Waimanalo | 89.16 | 90.25 | 101.2 |

are complicated because this comparison indicates the combined effect of milling and clarification. So far as can be determined from available data, average clarification results at Petree process factories have been less satisfactory than in the previous year in about the same proportion as at factories using filter presses.

The reason for poorer results in clarification is reflected in figures for the amount of lime used. This has been reduced from .086 to .079 per cent on cane. At the increased grinding rate it has, no doubt, been necessary to reduce the volume of settlings, whether they are returned to the mill or filtered. The volume of settlings can be reduced by reducing the amount of lime, but with the average quantity of lime now used, such reduction can be made only at the expense of smaller increases in purity and increased losses through inversion.

The following figures bring out an interesting relation between lime used and impurities removed. The figures for impurities removed are calculated from apparent purities and are not absolute, but they are quite closely, though not exactly, comparable:

| | 1924 | 1925 | Per cent reduction in 1925 |
|---|---|---|---|
| Lime used per cent impurities in mixed juice | 3.71 | 3.41 | 8.09 |
| Per cent of total impurities removed | 11.0 | 9.64 | 12.36 |

On the whole, data in these Synopses for the past five or six years, strongly confirm the results of research on clarification at the Experiment Station and emphasize the need of developing filtration equipment better suited to the duties imposed on it.

The following figures for purity difference between first expressed juice and syrup show the combined effect of conditions at the mill and clarification during the last few years:

| Year | Purity difference first expressed juice to syrup |
|---|---|
| 1921 | 2.32 |
| 1922 | 1.88 |
| 1923 | 1.40 |
| 1924 | 1.54 |
| 1925 | 1.65 |

These figures show a decidedly unfavorable trend in the last two years.

*Filter Presses:* The following is based on data for factories which do not use the Petree process, in Table III. In the past three seasons the same percentage of press cake on cane has been reported and differences in the polarization of the press cake have been small. Both the polarization of the press cake and the loss in press cake per cent polarization in cane have increased .01 over last year.

*Evaporation:* The syrup was evaporated to 63.65 Brix. This is .33 higher than last year and is higher than in any previous year. 2.6 per cent more water was evaporated per hour than in 1924 and some 18 per cent more than in 1921. At this rate of evaporation, if the same amount of maceration had been applied

TABLE NO. 8

COMPARISON OF ACTUAL AND CALCULATED RECOVERIES

The factories are arranged in the order of the ratio of their recovery to that resulting from 100% extraction, reducing the molasses to 37.5 gravity purity, and eliminating all other losses. Factories reporting a recovery of over 101% of the available (Table No. 6) are omitted from this tabulation.

| No. | Factory | Milling | Boiling House | Over All |
|---|---|---|---|---|
| 1 | Hakalau | 98.93 | 101.48 | 100.55 |
| 2 | Pepeekeo | 98.10 | 102.17 | 100.39 |
| 3 | Lihue | 97.59 | 101.21 | 99.13 |
| 4 | Onomea | 98.73 | 100.06 | 99.00 |
| 5 | Honomu | 98.15 | 100.09 | 98.51 |
| 6 | Wailuku | 98.37 | 99.85 | 98.46 |
| 7 | Ewa | 97.99 | 99.89 | 98.21 |
| 8 | Pioneer | 97.38 | 100.09 | 97.93 |
| 9 | Haw. Sug | 97.75 | 99.95 | 97.93 |
| 10 | Paauhau | 97.57 | 99.97 | 97.87 |
| 11 | Koloa | 96.84 | 100.40 | 97.82 |
| 12 | Oahu | 97.29 | 100.14 | 97.80 |
| 13 | Kekaha | 98.36 | 98.58 | 97.14 |
| 14 | Waialua | 97.25 | 99.45 | 97.05 |
| 15 | McBryde | 97.21 | 99.45 | 96.92 |
| 16 | Maui Agr | 97.22 | 98.74 | 96.47 |
| 17 | Kilauea | 97.11 | 98.26 | 95.88 |
| 18 | Makee | 96.60 | 98.81 | 95.84 |
| 19 | Honokaa | 95.31 | 100.09 | 95.82 |
| 20 | Laupahoehoe | 97.04 | 98.51 | 95.80 |
| 21 | Hamakua | 96.67 | 98.08 | 95.33 |
| 22 | Kohala | 96.64 | 98.26 | 95.31 |
| 23 | Olaa | 96.90 | 97.89 | 95.27 |
| 24 | Waimea | 96.89 | 97.70 | 95.06 |
| 25 | Kaiwiki | 96.05 | 98.53 | 94.96 |
| 26 | Waiakea | 95.31 | 98.19 | 93.99 |
| 27 | Hutchinson | 96.42 | 96.67 | 93.61 |
| 28 | Haw. Agr | 96.72 | 95.34 | 92.49 |
| 29 | Union Mill | 94.91 | 96.84 | 92.29 |
| 30 | Olowalu | 98.17 | 93.64 | 92.24 |
| 31 | Halawa | 93.80 | 97.59 | 91.92 |
| 32 | Waianae | 96.73 | 94.37 | 91.72 |
| 33 | Hawi | 96.26 | 93.13 | 90.08 |
| 34 | Niulii | 90.29 | 95.22 | 86.57 |

as in 1924, the syrup would have been evaporated to 60.4 Brix. At the lower density, however, under otherwise equal conditions, the amount of water evaporated per hour would be slightly higher, indicating that with the same amount of maceration as last year, an average density of between 60.5 and 61.0 could have been attained. Under these circumstances, it does not seem that the reduction in maceration can be attributed entirely to lack of evaporator capacity.

*Commercial Sugar:* The polarization of the commercial sugar has been increased from 97.18 to 97.22. The change is in the right direction. The moisture content of the sugar has not been reduced in proportion to the increase in polarization; in fact, moisture figures carried to the third decimal place indicate a slight increase rather than a decrease. The deterioration factor has increased from .265 to .269. Such deterioration factors are not safe and more or less deterioration may be expected when sugar is not more thoroughly dried. The grain of the sugar has been considerably smaller in the past season. This has been a factor tending toward less satisfactory drying.

The increase in sugar polarization, under otherwise equal conditions, reduces sucrose recovery to the extent of .02. This is due to less molasses in the higher polarizing sugar. It does not indicate a reduction in recovery of available sugar.

*Low Grades:* Though lower syrup purity and increased grinding rate have increased the duty on low grade equipment approximately 4 per cent, the quality of the low grade work has materially improved. The gravity purity of the final molasses has been reduced to 37.32, the lowest average on record. As previously noted, a part of this decrease is due to a change in analytical methods, but after making full allowance for the probable effect of this change, this year's average is lower than that of any previous season. Figures for molasses density disclose the reason for the improvement, this year's average being 89.75 Brix, a figure .94 higher than the previous high mark last year.

Due to low purity and high density, the weight of molasses per cent cane and sucrose in molasses per cent cane are lower than in any previous year. Averages for sucrose in molasses per cent polarization of cane and per cent polarization of juice are lower than figures for any previous year except 1915. It is probable that lower averages in that year are because of incomplete molasses data rather than because these losses were actually lower, for at that time a large proportion of the factories did not report molasses weights and at most of these factories molasses purities were high.

In comparison with last year, better low grade work corresponds to an improvement in recovery of .15 or more, according to how much of the decrease in purity is actually attributable to improved work and how much to changes in analytical methods.

For the third successive season, Kahuku has established a new record in final molasses purity, reporting 32.46. Pepeekeo reported 32.96 purity, a figure lower than the previous record and 1.13 lower than the previous low average at this factory.

## Recoveries

Factors that have tended toward higher recoveries are higher initial purities, smaller decreases in purity from first expressed to mixed juice and lower molasses purities. Factors that have tended toward lower recoveries are lower extraction, less satisfactory work in clarification, larger losses in press cake, higher sugar polarization and larger undetermined losses. With the exception of clarification, these factors tending toward lower recoveries are small and have been more than offset by the factors tending toward higher recoveries. Both boiling house and total recoveries are higher than last year. Boiling house recovery increased .2. The present figure, 91.59, is the highest since 1909. A new record has been made in total recovery, the present figure, 89.11, being .17 higher than the previous record made last year.

The slightly poorer quality of the cane has caused a decrease in recovery per cent cane from 11.77 to 11.76. Actually, the decrease would have been .02 if the work had been of the same quality as in the previous season. The decrease of but .01 in recovery per cent cane indicates more efficient factory work this year.

Quality ratio figures give a similar indication of more efficient work. The 1924 figures are 8.25 quality ratio, with 8.26 tons of cane required to make a ton of sugar. The 1925 figures are 8.28 quality ratio with 8.27 tons of cane required. The 1924 cane requirement was then .01 ton more than indicated by quality ratio figures, while this year the cane requirement was .01 ton less than the quality ratio, a net gain of .02 ton.

While the results as a whole are better than in 1924, the quality of the work is still below the 1923 standard.

Table VIII, in which factories are ranked in the order of the ratio of actual recovery to a theoretical recovery calculated as indicated in the note accompanying the table, has been included again. A word of caution against drawing too close distinctions on the basis of these figures again seems desirable. As this table is now calculated, differences of 2 per cent or more in the figures in the third column are probably of definite significance but closer distinctions seem hardly justified. After a number of years study of these and other comparisons of a similar nature, the writer has come to the conclusion that no method has yet been devised for accurately expressing operating efficiency in a raw cane sugar factory as a simple percentage figure.

A summary of losses has been compiled in Table IX.

Mr. A. Brodie has made the calculations and compiled the tables in this Synopsis, with some assistance from others in this department.

## SUMMARY OF LOSSES

| FACTORY | POUNDS POLARIZATION PER TON OF CANE | | | | | | POLARIZATION PER 100 CANE | | | | | | POLARIZATION PER 100 POLARIZATION OF CANE | | | | | | Syrup Purity | FACTORY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bagasse | Press Cake | Molasses | Other Known | Undetermined | TOTAL | Bagasse | Press Cake | Molasses | Other Known | Undetermined | TOTAL | Bagasse | Press Cake | Molasses | Other Known | Undetermined | TOTAL | | |
| H. C. & S. Co. | 8.2 | 1.4 | 15.2 | ... | —3.0 | 21.8* | 0.41 | 0.07 | 0.76 | .... | —0.15 | 1.09* | 2.77 | 0.47 | 5.15 | ... | —0.98 | 7.41* | 88.23 | H. C. & S. Co. |
| Oahu | 7.6 | 1.4 | 17.6 | .... | 2.2 | 28.8† | 0.38 | 0.07 | 0.88 | ... | 0.11 | 1.44† | 2.71 | 0.48 | 6.31 | ... | 0.77 | 10.27† | 87.10 | Oahu |
| Ewa | 5.4 | 1.2 | 18.8 | ... | 1.0 | 26.4 | 0.27 | 0.06 | 0.94 | ... | 0.05 | 1.32 | 2.01 | 0.42 | 7.14 | ... | 0.42 | 9.99 | 85.97 | Ewa |
| Waialua | 7.6 | 1.4 | 19.4 | ... | 2.8 | 31.2 | 0.38 | 0.07 | 0.97 | ... | 0.14 | 1.56 | 2.75 | 0.52 | 7.04 | .... | 0.98 | 11.29 | 85.9 | Waialua |
| Pioneer | 7.2 | 1.0 | 18.6 | ... | 1.8 | 28.6 | 0.36 | 0.05 | 0.93 | ... | 0.09 | 1.43 | 2.62 | 0.34 | 6.74 | .... | 0.62 | 10.32 | 86.37 | Pioneer |
| Olaa | 8.0 | 1.6 | 20.6 | .... | 2.0 | 32.2 | 0.40 | 0.08 | 1.03 | ... | 0.10 | 1.61 | 3.10 | 0.64 | 8.04 | ... | 0.81 | 12.59 | 86.6 | Olaa |
| Haw. Sug. | 6.8 | 1.0 | 19.0 | ... | 0.4 | 27.2† | 0.34 | 0.05 | 0.95 | .... | 0.02 | 1.36† | 2.25 | 0.35 | 6.26 | ... | 0.11 | 8.97† | 88.56 | Haw. Sug. Co. |
| Maui Agr. | 8.4 | ... | 23.6 | .... | 1.4 | 33.4† | 0.42 | ... | 1.18 | .... | 0.07 | 1.67† | 2.78 | ... | 7.85 | ... | 0.47 | 11.10† | 87.88 | Maui Agr. |
| Lihue | 6.0 | 0.8 | 19.4 | ... | 1.8 | 28.0 | 0.30 | 0.04 | 0.97 | ... | 0.09 | 1.40 | 2.41 | 0.29 | 7.75 | ... | 0.76 | 11.21 | 83.65 | Lihue |
| Onomea | 3.0 | 0.2 | 16.2 | ... | 0.8 | 20.2 | 0.15 | 0.01 | 0.81 | ... | 0.04 | 1.01 | 1.27 | 0.13 | 6.61 | ... | 0.30 | 8.31 | 87.30 | Onomea |
| Hilo | 4.0 | 0.6 | 17.4 | ... | 0.6 | 22.0* | 0.20 | 0.03 | 0.87 | ... | 0.00 | 1.10* | 1.61 | 0.27 | 7.17 | ... | 0.03 | 9.08* | 86.00 | Hilo |
| Kekaha | 4.4 | 1.0 | 22.8 | .... | 2.0 | 30.2 | 0.22 | 0.05 | 1.14 | ... | 0.10 | 1.51 | 1.64 | 0.34 | 8.29 | ... | 0.73 | 11.00 | 85.7 | Kekaha |
| Honolulu | 7.4 | 0.4 | ... | 1.0 | .... | ... | 0.37 | 0.02 | .... | 0.05 | .... | ... | 2.65 | 0.18 | .... | 0.34 | ... | ... | 86.37 | Honolulu |
| Haw. Agr. | 8.2 | 0.8 | 16.4 | ... | 11.0 | 36.4 | 0.41 | 0.04 | 0.82 | ... | 0.55 | 1.82 | 3.28 | 0.32 | 6.56 | ... | 4.36 | 14.52 | 86.97 | Haw. Agr. Co. |
| Hakalau | 2.6 | 0.4 | 16.4 | ... | 0.6 | 20.0 | 0.13 | 0.02 | 0.82 | ... | 0.03 | 1.00 | 1.07 | 0.12 | 6.48 | ... | 0.26 | 7.93 | 85.5 | Hakalau |
| Wailuku | 4.6 | 1.6 | 20.2 | ... | —0.2 | 26.2 | 0.23 | 0.08 | 1.01 | ... | —0.01 | 1.31 | 1.63 | 0.54 | 7.17 | ... | —0.07 | 9.27 | 86.7 | Wailuku |
| Makee | 8.4 | 1.0 | 22.2 | .... | 1.8 | 33.4 | 0.42 | 0.05 | 1.11 | ... | 0.09 | 1.67 | 3.40 | 0.36 | 8.95 | ... | 0.75 | 13.46 | 84.68 | Makee |
| McBryde | 7.6 | 0.4 | 20.8 | ... | 0.6 | 29.4 | 0.38 | 0.02 | 1.04 | .... | 0.03 | 1.47 | 2.79 | 0.19 | 7.65 | ... | 0.20 | 10.83 | 86.32 | McBryde |
| Honokaa | 10.6 | 0.8 | 17.2 | .... | 0.4 | 29.0 | 0.53 | 0.04 | 0.86 | ... | 0.02 | 1.45 | 4.69 | 0.38 | 7.65 | ... | 0.14 | 12.86 | 85.09 | Honokaa |
| Laupahoehoe | 7.6 | 0.4 | 15.8 | ... | 4.4 | 28.2 | 0.38 | 0.02 | 0.79 | ... | 0.22 | 1.41 | 2.96 | 0.17 | 6.18 | ... | 1.71 | 11.02 | 87.47 | Laupahoehoe |
| Pepeekeo | 4.6 | 0.4 | 14.4 | ... | 1.0 | 20.4 | 0.23 | 0.02 | 0.72 | ... | 0.05 | 1.02 | 1.90 | 0.20 | 5.88 | ... | 0.39 | 8.37 | 85.4 | Pepeekeo |
| Hamakua | 8.6 | ... | 20.8 | ... | 1.2 | 30.6 | 0.43 | ... | 1.04 | .... | 0.06 | 1.53 | 3.33 | ... | 8.06 | ... | 0.49 | 11.88 | 87.29 | Hamakua |
| Kahuku | 7.8 | 0.8 | 17.6 | .... | —1.6 | 24.6 | 0.39 | 0.04 | 0.88 | ... | — 0.09 | 1.22* | 3.29 | 0.32 | 7.38 | ... | —0.74 | 10.25* | 83.11 | Kahuku |
| Paauhau | 5.8 | 0.2 | 16.8 | ... | 1.4 | 24.2 | 0 29 | 0.01 | 0.84 | ... | 0.07 | 1.21 | 2.43 | 0.13 | 7.10 | ... | 0.62 | 10.28 | 85.75 | Paauhau |
| Honomu | 4.6 | 0.6 | 17.6 | ... | 0.6 | 23.4 | 0.23 | 0.03 | 0.88 | ... | 0.03 | 1.17 | 1.85 | 0.24 | 6.98 | ... | 0.25 | 9.32 | 86.7 | Honomu |
| Koloa | 7.8 | 1.8 | 19.2 | ... | 2.0 | 30.8 | 0.39 | 0.09 | 0.96 | .... | 0.10 | 1.54 | 3.16 | 0.70 | 7.78 | ... | 0.78 | 12.42 | 83.8 | Koloa |
| Hutchinson | 8.8 | 1.4 | 20.2 | ... | 4.4 | 34.8 | 0.44 | 0.07 | 1.01 | ... | 0.22 | 1.74 | 3.58 | 0.55 | 8.24 | ... | 1.77 | 14.14 | 86.33 | Hutchinson |
| Waiakea | 11.8 | 1.6 | 18.8 | ... | 3.2 | 35.4 | 0.59 | 0.08 | 0.94 | ... | 0.16 | 1.77 | 4.69 | 0.65 | 7.49 | ... | 1.26 | 14.09 | 85.83 | Waiakea |
| Hawi | 9.4 | 1.2 | ... | .... | 31.8 | 42.4 | 0.47 | 0.06 | ... | .. | 1.59 | 2.12 | 3.74 | 0.49 | .... | ... | 12.54 | 16.77 | 86.9 | Hawi |
| Kaiwiki | 10.0 | 1.4 | 18.8 | ... | 1.6 | 31.8 | 0.50 | 0.07 | 0.94 | ... | 0.08 | 1.59 | 3.95 | 0.58 | 7.40 | ... | 0.65 | 12.58 | 86.47 | Kaiwiki |
| Waianae | 9.2 | 1.6 | ... | ... | 39.8 | 50.6 | 0.46 | 0.08 | ... | ... | 1.99 | 2.53 | 3.27 | 0.57 | .... | ... | 14.21 | 18.05 | 83.14 | Waianae |
| Kohala | 8.4 | 2.4 | 17.8 | .... | 1.4 | 30.00 | 0.42 | 0.12 | 0.89 | ... | 0.07 | 1.50 | 3.36 | 0.98 | 7.05 | ... | 0.56 | 11.95 | 86.97 | Kohala |
| Kilauea | 6.8 | 2.8 | 23.6 | ... | 3.8 | 37.0 | 0.34 | 0.14 | 1.18 | . | 0.19 | 1.85 | 2.89 | 1.18 | 10.03 | ... | 1.65 | 15.75 | 81.8 | Kilauea |
| Kaeleku | 12.0 | 1.8 | 18.2 | ... | 1.2 | 32.2 | 0.60 | 0.09 | 0.91 | ... | 0.06 | 1.66* | 4.95 | 0.75 | 7.50 | ... | 0.54 | 13.74* | 84.79 | Kaeleku |
| Waimanalo | 3.2 | 1.4 | 22.4 | ... | 0.4 | 27.4* | 0.16 | 0.07 | 1.12 | ... | 0.02 | 1.37* | 1.27 | 0.54 | 8.93 | ... | 0.15 | 10.89* | 82.21 | Waimanalo |
| Union Mill | 12.2 | 2.6 | ... | ... | 22.2 | 37.0 | 0.61 | 0.13 | ... | ... | 1.11 | 1.85 | 5.09 | 1.06 | .... | ... | 9.28 | 15.43 | 85.8 | Union Mill |
| Halawa | 14.4 | 3.4 | ... | .... | 20.8 | 38.6 | 0.72 | 0.17 | ... | ... | 1.04 | 1.93 | 6.20 | 1.45 | .... | ... | 8.99 | 16.64 | 84.85 | Halawa |
| Waimea | 8.2 | 1.2 | ... | .... | 25.2 | 34.6 | 0.41 | 0.06 | ... | ... | 1.26 | 1.73 | 3.11 | 0.46 | .... | ... | 9.54 | 13.11 | 85.59 | Waimea |
| Olowalu | 4.8 | 1.4 | 25.8 | ... | 13.0 | 45.0 | 0.24 | 0.07 | 1.29 | .... | 0.65 | 2.25 | 1.83 | 0.53 | 10.04 | ... | 5.04 | 17.44 | 83.1 | Olowalu |
| Niulii | 21.2 | 1.6 | ... | ... | 26.4 | 49.2 | 1.06 | 0.08 | ... | .... | 1.32 | 2.46 | 9.71 | 0.70 | .... | ... | 12.12 | 22.53 | 83.53 | Niulii |

* A comparison of the available sucrose in the juice with the amount recovered in the boiling-house indicates that there is probably an error in some of the results reported from this factory.

† Sucrose.

# Sugar Prices

## 96° Centrifugals for the Period September 18, 1925, to December 15, 1925

| Date | Per Pound | Per Ton | Remarks |
|---|---|---|---|
| Sept. 18, 1925 | 4.18¢ | $83.60 | Philippines. |
| " 21 | 4.165 | 83.30 | Porto Ricos, 4.18; Cubas, 4.15. |
| " 22 | 4.12 | 82.40 | Spot Cubas. |
| " 23 | 4.135 | 82.70 | St. Croix, 4.12; Cubas, 4.15. |
| " 24 | 4.12 | 82.40 | Spot Cubas. |
| " 25 | 4.08 | 81.60 | Cubas. |
| " 28 | 4.02 | 80.40 | Cubas. |
| Oct. 1 | 3.93 | 78.60 | Cubas. |
| " 2 | 3.90 | 78.00 | Philippines. |
| " 5 | 3.93 | 78.60 | Philippines. |
| " 6 | 3.96 | 79.20 | Philippines. |
| " 8 | 3.95 | 79.00 | Porto Ricos, 3.96; Philippines, 3.94. |
| " 13 | 3.90 | 78.00 | Philippines. |
| " 15 | 3.86 | 77.20 | Cubas. |
| " 16 | 3.83 | 76.60 | Cubas. |
| " 19 | 3.80 | 76.00 | Cubas, 3.83, 3.77. |
| " 20 | 3.77 | 75.40 | Cubas. |
| " 23 | 3.74 | 74.80 | Philippines. |
| " 26 | 3.725 | 74.50 | Cubas, 3.74, 3.71. |
| " 27 | 3.71 | 74.20 | Cubas. |
| " 28 | 3.68 | 73.60 | Cubas. |
| " 30 | 3.77 | 75.40 | Cubas. |
| Nov. 4 | 3.90 | 78.00 | Cubas. |
| " 7 | 4.02 | 80.40 | Cubas. |
| " 12 | 4.115 | 82.30 | Philippines, 4.08; Cubas, 4.15. |
| " 13 | 4.1583 | 83.16 | Cubas, 4.14; Philippines, 4.125; Cubas, 4.21. |
| " 16 | 4.18 | 83.60 | Cubas. |
| " 17 | 4.05 | 81.00 | Cubas, 4.02, 4.08. |
| " 25 | 4.15 | 83.00 | Cubas. |
| " 30 | 4.24 | 84.80 | Cubas, 4.21, 4.27. |
| Dec. 2 | 4.15 | 83.00 | Cubas. |
| " 4 | 4.115 | 82.30 | Cubas, 4.15, 4.08. |
| " 5 | 4.15 | 83.00 | Cubas. |
| " 7 | 4.08 | 81.60 | Cubas. |
| " 10 | 4.02 | 80.40 | Cubas. |
| " 15 | 4.14 | 82.80 | Cubas. |

# ANNUAL SYNOPSIS OF MILL DATA--SHOWING RESULTS FROM 40 HAWAIIAN FACTORIES FOR CROP OF 1925

| Factory | Factory No. | Milling Plant (Sizes in Inches) | CANE Polarization | CANE % Fiber | CANE Tons per ton commercial sugar | CANE Tons ground per hour | CANE Tonnage ratio | BAGASSE Polarization | BAGASSE % Moisture | BAGASSE % Fiber | BAGASSE Pol. per 100 cane | BAGASSE Pol. per 100 pol. of cane | BAGASSE Pol. per 100 Fiber "Milling Loss" | BAGASSE Weight per 100 cane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co.** | 6 | K(4),2RC78(2),S72(2),12RM78(2) | 14.82 | 12.17 | 7.06 | 65.12‡ | 1.85 | 1.86 | 42.33 | 55.12 | 0.41 | 2.77 | 3.37 | 22.08 |
| Oahu | 20 | K(2),2RC78(2),S72(2),12RM78(2) | 13.98 | 12.31 | 7.78 | 60.22‡ | 1.71 | 1.70 | 42.26 | 55.31 | 0.38 | 2.71 | 3.07 | 22.26 |
| Ewa | 5 | K(2),2RC78,18RM78 | 13.22 | 11.67 | 8.16 | 84.96 | 1.72 | 1.24 | 43.78 | 54.31 | 0.27 | 2.01 | 2.28 | 21.49 |
| Waialua | 17 | K(2),2RC78,12RM78 | 13.80 | 13.00 | 7.96 | 64.90 | 1.84 | 1.66 | 40.98 | 56.66 | 0.38 | 2.75 | 2.93 | 22.94 |
| Pioneer | 10 | K,2RC72,S72,15RM72 | 13.85 | 13.10 | 7.87 | 78.25 | 2.17 | 1.46 | 44.96 | 52.78 | 0.36 | 2.62 | 2.77 | 24.83 |
| Olaa | 36 | K,S72,12RM78 | 12.79 | 12.81 | 8.74 | 57.28 | 2.03 | 1.67 | 43.90 | 53.66 | 0.40 | 3.10 | 3.11 | 23.76 |
| Haw. Sug. | 16 | K,2RC72,S72,12RM78 | 15.11 | 11.99 | 7.11 | 49.56 | 1.41 | 1.59 | 41.69 | 56.17 | 0.34 | 2.25 | 2.83 | 21.30 |
| Maui Agr.** | 21 | K(2),3RC66,18RM66 | 14.98 | 12.01 | 7.35 | 77.62 | 2.20 | 1.80 | 45.20 | 52.08 | 0.42 | 2.78 | 3.16 | 23.05 |
| Lihue | 27 | K,2RC78,S72,12RM78 | 12.54 | 12.61 | 8.73 | 63.62 | 1.81 | 1.34 | 42.15 | 55.84 | 0.30 | 2.41 | 2.40 | 22.58 |
| Onomea†† | 34 | 2RC60,S54,12RM66 | 12.19 | 13.04 | 8.71 | 47.63 | 1.89 | 0.72 | 38.07 | 60.85 | 0.15 | 1.27 | 1.18 | 21.44 |
| Hilo | 33 | K,2RC60,12RM66 | 12.13 | 13.63 | 8.82 | 40.53 | 1.61 | 0.86 | 38.55 | 60.21 | 0.20 | 1.61 | 1.43 | 22.64 |
| Kekaha | 25 | 2RC54,15RM60 | 13.70 | 12.30 | 7.93 | 39.59 | 1.58 | 1.08 | 39.27 | 59.13 | 0.22 | 1.64 | 1.83 | 20.81 |
| Honolulu | 13 | K(2),S54,2RC78,9RM78 | 13.94 | 12.29 | 8.26 | 43.43 | 1.54 | 1.75 | 39.46 | 58.08 | 0.37 | 2.65 | 3.01 | 21.15 |
| Haw. Agr.†† | 30 | 3RC60,12RM66 | 12.56 | 12.72 | 9.03 | 47.94 | 1.90 | 1.85 | 40.54 | 57.00 | 0.41 | 3.28 | 3.24 | 22.31 |
| Hakalau | 7 | 2RC54,12RM9-60,3 66 | 12.60 | 12.41 | 8.34 | 32.33 | 1.55 | 0.67 | 36.89 | 62.17 | 0.13 | 1.07 | 1.08 | 19.96 |
| Wailuku | 2 | K,2RC72,12RM78 | 14.11 | 11.82 | 7.61 | 40.61 | 1.15 | 1.16 | 38.51 | 59.79 | 0.23 | 1.63 | 1.95 | 19.77 |
| Makee | 14 | K,2RC72,S72,9RM72 | 12.39 | 13.37 | 9.07 | 49.17 | 2.05 | 1.81 | 40.17 | 57.28 | 0.42 | 3.40 | 3.16 | 23.33 |
| McBryde | 12 | K,2RC72,S72,9RM84 | 13.56 | 13.66 | 8.01 | 39.63 | 1.21 | 1.55 | 42.05 | 55.84 | 0.38 | 2.79 | 2.78 | 24.47 |
| Honokaa | 35 | K(2),2RC66,12RM66 | 11.23 | 12.65 | 9.89 | 39.03 | 1.55 | 2.11 | 46.33 | 50.78 | 0.53 | 4.69 | 4.16 | 24.92 |
| Laupahoehoe | 41 | K,2RC54,9RM60 | 12.77 | 13.32 | 8.53 | 27.24 | 1.63 | 1.65 | 39.88 | 58.00 | 0.38 | 2.96 | 2.85 | 22.93 |
| Pepeekeo | 19 | 2RC54,9RM60 | 12.21 | 11.58 | 8.70 | 29.50 | 1.77 | 1.21 | 37.74 | 60.65 | 0.23 | 1.90 | 2.00 | 19.10 |
| Hamakua* | 15 | K,2RC60,12RM60 | 12.92 | 14.13 | 8.53 | 29.80 | 1.43 | 1.65 | 43.33 | 54.27 | 0.43 | 3.33 | 3.04 | 26.03 |
| Kahuku | 43 | K,2RC60,S54,9RM72 | 11.97 | 14.59 | 9.10 | 33.46 | 1.39 | 1.51 | 41.65 | 56.11 | 0.39 | 3.29 | 2.69 | 26.03 |
| Paauhau†† | 24 | 2RC60,12RM66 | 11.82 | 12.86 | 9.13 | 29.79 | 1.18 | 1.34 | 37.94 | 60.09 | 0.29 | 2.43 | 2.23 | 21.40 |
| Honomu | 37 | 3RC60,9RM60 | 12.65 | 12.09 | 8.52 | 26.78 | 1.61 | 1.14 | 39.62 | 58.68 | 0.23 | 1.85 | 1.94 | 20.60 |
| Koloa | 38 | K,2RC60,12RM66 | 12.37 | 14.55 | 8.96 | 32.84 | 1.30 | 1.55 | 39.65 | 57.81 | 0.39 | 3.16 | 2.68 | 25.17 |
| Hutchinson†† | 31 | 2RC60,9RM60 | 12.33 | 11.20 | 9.17 | 31.13 | 1.87 | 2.32 | 37.88 | 58.85 | 0.44 | 3.58 | 3.94 | 19.04 |
| Waiakea | 3 | K,2RC60,9RM60 | 12.59 | 14.32 | 8.97 | 26.37 | 1.58 | 2.22 | 42.97 | 54.05 | 0.59 | 4.69 | 4.11 | 26.54 |
| Hawi | 26 | K(2),3RC48,12RM3 48,9 54 | 12.64 | 12.46 | 9.18 | 24.55 | 1.45 | 2.07 | 42.62 | 54.47 | 0.47 | 3.74 | 3.80 | 22.86 |
| Kaiwiki | 32 | K,2RC60,9RM60 | 12.70 | 13.66 | 8.72 | 26.43 | 1.59 | 2.12 | 39.58 | 57.61 | 0.50 | 3.95 | 3.68 | 23.71 |
| Waianae | 9 | K(2),12RM60 | 13.99 | 14.73 | 8.43 | 25.87 | 1.55 | 1.77 | 40.35 | 56.99 | 0.46 | 3.27 | 3.11 | 25.85 |
| Kohala | 40 | K(2),3RC60,9RM60 | 12.56 | 12.61 | 8.78 | 26.21 | 1.57 | 1.92 | 39.98 | 57.38 | 0.42 | 3.36 | 3.35 | 21.97 |
| Kilauea†† | 23 | K,S,3RC60,9RM60 | 11.75 | 13.22 | 9.81 | 25.6 | 1.54 | 1.47 | 40.50 | 57.20 | 0.34 | 2.89 | 2.57 | 23.11 |
| Kaeleku | 47 | K,2RC54,9RM60 | 12.06 | 14.21 | 9.29 | 28.65 | 1.72 | 2.42 | 39.13 | 57.67 | 0.60 | 4.95 | 4.20 | 24.63 |
| Waimanalo | 1 | K,3RC54,9RM54 | 12.53 | 14.23 | 8.62 | 26.29 | 1.95 | 0.69 | 37.42 | 61.50 | 0.16 | 1.27 | 1.12 | 23.14 |
| Union Mill | 11 | K,9RM60 | 12.02 | 14.17 | 9.47 | 20.01 | 1.60 | 2.41 | 40.52 | 56.27 | 0.61 | 5.09 | 4.28 | 25.40 |
| Halawa | 29 | K,2RC60,6RM50 | 11.53 | 13.90 | 10.06 | 13.52 | 1.56 | 2.95 | 38.83 | 57.33 | 0.72 | 6.20 | 5.15 | 24.25 |
| Waimea | 4 | 2RC48,12RM42 | 13.20 | 12.27 | 8.42 | 13.60 | 1.33 | 1.95 | 38.61 | 58.37 | 0.41 | 3.11 | 3.29 | 21.02 |
| Olowalu | 18 | K,3RC48,9RM48 | 12.89 | 13.03 | 9.05 | 16.79 | 1.57 | 1.11 | 37.30 | 60.95 | 0.24 | 1.83 | 1.82 | 21.38 |
| Niulii | 39 | K,9RM54 | 10.93 | 14.62 | 11.39 | 17.04 | 1.68 | 3.38 | 48.87 | 46.68 | 1.06 | 9.71 | 7.24 | 31.34 |
| True Average, 1925 | 1925 | | 13.22 | 12.74 | 8.27 | 45.31 | 1.71 | 1.58 | 41.56 | 56.18 | 0.36 | 2.71 | 2.82 | 22.67 |
| " " 1924 | 1924 | | 13.26 | 12.74 | 8.26 | 43.63 | 1.62 | 1.56 | 41.58 | 56.19 | 0.35 | 2.67 | 2.78 | 22.67 |
| " " 1923 | 1923 | | 12.78 | 12.82 | 8.56 | 42.03 | 1.56 | 1.55 | 41.56 | 56.18 | 0.35 | 2.77 | 2.76 | 22.80 |
| " " 1922 | 1922 | | 12.97 | 12.95 | 8.62 | 39.93 | 1.54 | 1.69 | 41.51 | 56.05 | 0.39 | 3.02 | 3.02 | 23.09 |
| " " 1921 | 1921 | | 13.12 | 12.80 | 8.61 | 36.58 | 1.40 | 1.50 | 41.20 | 56.58 | 0.34 | 2.57 | 2.64 | 22.58 |
| " " 1920 | 1920 | | 13.64 | 12.64 | 8.12 | 39.34 | .... | 1.56 | 41.05 | 56.68 | 0.35 | 2.55 | 2.75 | 22.29 |
| " " 1919 | 1919 | | 13.74 | 12.49 | 7.94 | .... | .... | 1.67 | 41.57 | 56.05 | 0.37 | 2.70 | 2.97 | 22.27 |
| " " 1918 | 1918 | | 12.97 | 12.50 | 8.51 | .... | .... | 1.59 | 42.70 | 55.04 | 0.36 | 2.79 | 2.90 | 22.74 |
| " " 1917 | 1917 | | 13.76 | 12.62 | 8.03 | .... | .... | 1.78 | 42.26 | 55.31 | 0.41 | 2.95 | 3.22 | 22.83 |
| " " 1916 | 1916 | | 13.45 | 12.74 | 8.16 | .... | .... | 1.81 | 42.49 | 54.98 | 0.42 | 3.13 | 3.30 | 23.19 |

| Factory | Factory No. | FIRST EXPRESSED JUICE Brix | FIRST EXPRESSED JUICE Polarization | FIRST EXPRESSED JUICE Purity | FIRST EXPRESSED JUICE Pol. of cane x 100 / Polarization | MIXED JUICE Brix | MIXED JUICE Polarization | MIXED JUICE Purity | MIXED JUICE Weight per 100 cane | MIXED JUICE Pol. per 100 cane | MIXED JUICE Pol. per 100 pol. of cane "Extraction" | MIXED JUICE Extraction Ratio | LAST EXPRESSED JUICE Polarization | LAST EXPRESSED JUICE Purity | MACERATION WATER Weight per 100 cane | MACERATION WATER Dilution % normal juice |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co.** | 6 | 20.37 | 18.33 | 89.99 | 80.9 | 14.85 | 13.10 | 88.23 | 109.47 | 14.41 | 97.23 | 0.23 | 2.18 | 73.02 | 31.55 | [illegible] |
| Oahu | 20 | 19.50 | 17.12 | 87.8 | 80.8 | 14.11 | 12.21* | 86.54 | 111.33 | 13.60 | 97.29 | 0.22 | 1.84 | 69.96 | 33.59 | [illegible] |
| Ewa | 5 | 18.38 | 15.99 | 87.00 | 82.7 | 13.81 | 11.57 | 83.78 | 111.98 | 12.95 | 97.99 | 0.17 | 1.32 | 65.02 | 33.47 | [illegible] |
| Waialua | 17 | 18.76 | 16.56 | 88.3 | 83.3 | 13.82 | 11.76 | 85.1 | 114.12 | 13.42 | 97.25 | 0.21 | 2.35 | 70.4 | 37.06 | [illegible] |
| Pioneer | 10 | 19.84 | 17.59 | 88.66 | 78.7 | 15.12 | 12.93 | 85.52 | 104.31 | 13.48 | 97.38 | 0.20 | 0.81 | 64.88 | 29.14 | [illegible] |
| Olaa | 36 | 17.38 | 15.28 | 87.9 | 83.7 | 13.08 | 11.12 | 85.0 | 111.44 | 12.39 | 96.90 | 0.24 | 1.00 | 68.4 | 35.20 | [illegible] |
| Haw. Sug. | 16 | 20.00 | 17.80 | 89.00 | 84.9 | 11.98 | 13.08* | 87.32 | 112.90 | 14.77 | 97.75 | 0.19 | 2.76 | 74.28 | 34.20 | [illegible] |
| Maui Agr.** | 21 | 19.80 | 17.66 | 89.19 | 84.8 | 13.82 | 12.21* | 88.35 | 119.29 | 14.56 | 97.22 | 0.23 | 2.08 | 66.88 | 42.34 | [illegible] |
| Lihue | 27 | 18.56 | 15.98 | 86.1 | 78.5 | 14.08 | 11.69 | 83.0 | 104.70 | 12.24 | 97.59 | 0.19 | 2.10 | 67.7 | 27.28 | [illegible] |
| Onomea†† | 34 | 16.22 | 14.30 | 88.17 | 85.2 | 12.24 | 10.51 | 85.86 | 114.52 | 12.04 | 98.73 | 0.10 | 1.27 | 67.20 | 35.96 | [illegible] |
| Hilo | 33 | 16.08 | 13.9 | 86.44 | 87.3 | 12.12 | 10.29 | 84.9 | 115.98 | 11.94 | 98.39 | 0.12 | 1.91 | 69.46 | 38.62 | [illegible] |
| Kekaha | 25 | 18.47 | 16.29 | 88.2 | 84.1 | 14.15 | 12.01 | 84.9 | 112.19 | 13.48 | 98.36 | 0.13 | 0.86 | 67.7 | 33.00 | [illegible] |
| Honolulu | 13 | 19.53 | 17.00 | 87.0 | 82.0 | 13.39 | 11.23 | 83.89 | 120.85 | 13.57 | 97.35 | 0.22 | 1.19 | 71.1 | 42.00 | [illegible] |
| Haw. Agr.†† | 30 | 17.71 | 15.67 | 88.48 | 80.2 | 14.48 | 12.44 | 85.91 | 97.68 | 12.15 | 96.72 | 0.26 | 2.94 | 74.62 | 19.99 | [illegible] |
| Hakalau | 7 | 17.04 | 15.03 | 88.2 | 83.8 | 12.19 | 10.31 | 84.6 | 120.91 | 12.47 | 98.93 | 0.09 | 1.35 | 71.1 | 40.87 | [illegible] |
| Wailuku | 2 | 19.71 | 17.81 | 90.1 | 79.2 | 13.75 | 11.79 | 85.7 | 117.70 | 13.88 | 98.37 | 0.14 | 1.06 | 67.9 | 37.47 | [illegible] |
| Makee | 14 | 18.42 | 16.07 | 87.25 | 77.1 | 13.23 | 11.10 | 83.91 | 107.82 | 11.97 | 96.60 | 0.25 | 3.08 | 70.97 | 31.15 | [illegible] |
| McBryde | 12 | 19.19 | 16.78 | 87.14 | 80.8 | 13.00 | 10.99 | 84.54 | 119.95 | 13.18 | 97.21 | 0.20 | 1.97 | 73.51 | 44.42 | [illegible] |
| Honokaa | 35 | 16.24 | 14.25 | 87.75 | 78.8 | 12.13 | 10.14 | 83.59 | 105.49 | 10.70 | 95.31 | 0.37 | 2.27 | 72.99 | 30.40 | [illegible] |
| Laupahoehoe | 41 | 17.14 | 15.37 | 89.67 | 83.1 | 12.11 | 10.42 | 86.04 | 118.87 | 12.39 | 97.04 | 0.22 | 2.81 | 77.84 | 41.80 | [illegible] |
| Pepeekeo | 19 | 16.66 | 14.62 | 87.7 | 83.5 | 13.04 | 10.94 | 83.9 | 109.53 | 11.98 | 98.10 | 0.16 | 2.18 | 75.0 | 28.63 | [illegible] |
| Hamakua* | 15 | 18.86 | 17.03 | 90.30 | 75.8 | 15.31 | 13.38 | 87.33 | 93.35 | 12.49 | 96.67 | 0.23 | 2.30 | 68.87 | 19.38 | [illegible] |
| Kahuku | 43 | 17.43 | 14.73 | 84.51 | 81.3 | 12.58 | 10.22 | 81.24 | 113.23 | 11.58 | 96.71 | 0.23 | 1.76 | 67.56 | 39.26 | [illegible] |
| Paauhau†† | 24 | 16.98 | 14.77 | 86.98 | 80.0 | 12.45 | 10.45 | 83.94 | 110.41 | 11.53 | 97.57 | 0.19 | 2.20 | 68.11 | 31.81 | [illegible] |
| Honomu | 37 | 17.18 | 15.20 | 88.5 | 83.2 | 12.64 | 10.63 | 84.1 | 116.81 | 12.42 | 98.15 | 0.15 | 1.47 | 66.8 | 37.41 | [illegible] |
| Koloa | 38 | 18.61 | 15.95 | 85.7 | 77.6 | 13.16 | 10.76 | 81.8 | 111.34 | 11.98 | 96.84 | 0.22 | 1.15 | 60.8 | 36.51 | [illegible] |
| Hutchinson†† | 31 | 16.81 | 14.75 | 87.75 | 83.6 | 14.08 | 11.95 | 84.87 | 99.46 | 11.89 | 96.42 | 0.32 | 2.38 | 71.05 | 18.49 | [illegible] |
| Waiakea | 3 | 17.97 | 15.78 | 87.81 | 79.8 | 13.62 | 11.59 | 85.10 | 103.51 | 12.00 | 95.31 | 0.33 | 3.10 | 74.52 | 30.05 | [illegible] |
| Hawi | 26 | 18.02 | 16.10 | 89.3 | 78.5 | 13.76 | 11.79 | 85.7 | 103.18 | 12.17 | 96.26 | 0.30 | 3.26 | 71.2 | 26.04 | [illegible] |
| Kaiwiki | 32 | 18.08 | 15.96 | 88.27 | 79.6 | 12.83 | 10.98 | 85.58 | 111.11 | 12.20 | 96.05 | 0.29 | 2.92 | 75.45 | 34.82 | [illegible] |
| Waianae | 9 | 21.07 | 18.04 | 85.62 | 77.6 | 13.43 | 10.92 | 81.31 | 123.97 | 13.54 | 96.73 | 0.22 | 2.46 | 66.49 | 49.82 | [illegible] |
| Kohala | 40 | 17.09 | 14.96 | 87.54 | 84.0 | 12.33 | 10.59 | 85.89 | 114.59 | 12.14 | 96.64 | 0.27 | 2.33 | 72.81 | 36.56 | [illegible] |
| Kilauea†† | 23 | 17.91 | 15.10 | 84.3 | 77.8 | 13.52 | 10.88 | 80.5 | 104.89 | 11.41 | 97.11 | 0.22 | 1.77 | 63.9 | 28.00 | [illegible] |
| Kaeleku | 47 | 16.79 | 14.47 | 86.16 | 83.4 | 13.21 | 11.04 | 83.56 | 103.87 | 11.46 | 95.05 | 0.35 | 4.72 | 75.52 | 28.50 | [illegible] |
| Waimanalo | 1 | 18.66 | 15.79 | 84.62 | 79.4 | 13.82 | 11.18 | 80.90 | 110.65 | 12.37 | 98.73 | 0.09 | 1.90 | 64.0 | 33.78 | [illegible] |
| Union Mill | 11 | 17.2 | 14.7 | 85.5 | 81.8 | 12.9 | 10.75 | 83.3 | 106.15 | 11.41 | 94.91 | 0.36 | 3.26 | 75.0 | 31.55 | [illegible] |
| Halawa | 29 | 16.55 | 14.16 | 85.56 | 81.4 | 12.83 | 10.74 | 83.72 | 100.70 | 10.82 | 93.80 | 0.45 | 5.86 | 76.91 | 24.95 | [illegible] |
| Waimea | 4 | 18.58 | 16.18 | 87.08 | 81.6 | 14.61 | 12.28 | 84.03 | 104.17 | 12.79 | 96.89 | 0.25 | 3.30 | 69.53 | 25.19 | [illegible] |
| Olowalu | 18 | 18.52 | 16.08 | 86.8 | 80.2 | 13.15 | 10.80 | 82.1 | 117.14 | 12.65 | 98.17 | 0.14 | 1.66 | 63.6 | 38.52 | [illegible] |
| Niulii | 39 | 15.66 | 13.41 | 85.63 | 81.5 | 12.44 | 10.35 | 83.20 | 95.28 | 9.87 | 90.29 | 0.66 | 4.89 | 75.93 | 26.62 | [illegible] |
| True Average, 1925 | 1925 | 18.42 | 16.19 | 87.92 | 81.64 | 13.60 | 11.59 | 85.20 | 110.96 | 12.86 | 97.29 | 0.21 | 1.94 | 69.71 | 33.63 | ... |
| " " 1924 | 1924 | 18.51 | 16.26 | 87.86 | 81.55 | 13.52 | 11.50 | 85.05 | 112.23 | 12.91 | 97.33 | 0.21 | 1.96 | 71.62 | 34.90 | ... |
| " " 1923 | 1923 | 18.09 | 15.75 | 87.05 | 81.1 | 13.13 | 11.06 | 84.27 | 112.32 | 12.42 | 97.23 | 0.22 | 1.79 | 68.31 | 35.12 | ... |
| " " 1922 | 1922 | 18.44 | 16.01 | 86.84 | 81.0 | 13.46 | 11.27 | 83.73 | 111.48 | 12.58 | 96.98 | 0.23 | 1.93 | 69.13 | 34.75 | ... |
| " " 1921 | 1921 | 18.74 | 16.16 | 86.22 | 81.2 | 13.25 | 10.97 | 82.77 | 116.50 | 12.79 | 97.43 | 0.20 | 1.68 | 65.89 | 39.30 | ... |
| " " 1920 | 1920 | 19.32 | 16.85 | 87.24 | 80.9 | 13.48 | 11.31 | 83.87 | 117.35 | 13.29 | 97.45 | 0.20 | 1.65 | 68.20 | 39.95 | ... |
| " " 1919 | 1919 | 19.17 | 16.74 | 87.34 | 82.0 | 13.39 | 11.29 | 84.29 | 118.29 | 13.37 | 97.30 | 0.22 | 1.70 | 68.53 | 40.80 | ... |
| " " 1918 | 1918 | 18.26 | 15.92 | 87.18 | 81.3 | 12.92 | 10.85 | 83.99 | 116.05 | 12.60 | 97.21 | 0.22 | 1.56 | 69.52 | 38.99 | ... |
| " " 1917 | 1917 | 19.14 | 16.85 | 88.02 | 81.6 | 13.48 | 11.45 | 84.88 | 116.53 | 13.34 | 97.05 | 0.23 | 1.71 | 71.15 | 39.39 | ... |
| " " 1916 | 1916 | 18.64 | 16.34 | 87.70 | 82.3 | 13.17 | 11.14 | 84.59 | 116.99 | 13.03 | 96.87 | 0.25 | 1.73 | 71.71 | 39.85 | ... |

| Factory | Factory No. | Clarified juice purity | SYRUP Brix | SYRUP Purity | SYRUP Increase in Purity | PRESS CAKE Polarization | PRESS CAKE Weight per 100 cane | PRESS CAKE Pol. per 100 cane | PRESS CAKE Pol. per 100 pol. of cane | LIME USED (Weight Per 100 Cane) In Juice | LIME USED In Settlings | LIME USED Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co.** | 6 | 88.23 | 65.33 | 88.23 | .... | 1.22 | 1.65 | 0.07 | 0.47 | 0.10 | . | 0.10 |
| Oahu | 20 | 86.65 | 61.71 | 87.10 | 0.56* | 3.40 | 1.96 | 0.07 | 0.48 | 0.07 | 0.02 | 0.09 |
| Ewa | 5 | 85.42 | 68.49 | 85.97 | 2.19 | 2.48 | 2.24 | 0.06 | 0.42 | 0.07 | 0.01 | 0.08 |
| Waialua | 17 | 86.7 | 66.07 | 85.9 | 0.8 | 2.50 | 2.85 | 0.07 | 0.52 | .. | . | 0.10 |
| Pioneer | 10 | 86.41 | 64.88 | 86.37 | 0.85 | 1.45 | 3.23 | 0.05 | 0.34 | 0.06 | .... | 0.06 |
| Olaa | 36 | 86.7 | 63.28 | 86.6 | 1.6 | 3.01 | 1.63 | 0.08 | 0.64 | | . | 0.08 |
| Haw. Sug. | 16 | 87.48 | 64.41 | 88.56 | 1.24* | 2.08 | 2.55 | 0.05 | 0.35 | 0.06 | 0.01 | 0.07 |
| Maui Agr.** | 21 | 88.35 | 64.66 | 87.88 | .... | .... | ... | .. | ... | 0.07 | . | 0.07 |
| Lihue | 27 | 83.6 | 64.97 | 83.65 | 0.65 | 1.57 | 2.32 | 0.04 | 0.29 | . | . | 0.08 |
| Onomea†† | 34 | 87.00 | 66.69 | 87.30 | 1.44 | 0.65 | 2.37 | 0.01 | 0.13 | 0.07 | .... | 0.07 |
| Hilo | 33 | 85.94 | 67.41 | 86.00 | 1.1 | 1.43 | 2.32 | 0.03 | 0.27 | ... | . | 0.07 |
| Kekaha | 25 | 85.9 | 61.50 | 85.7 | 0.8 | 1.66 | 2.78 | 0.05 | 0.34 | 0.06 | 0.01 | 0.07 |
| Honolulu | 13 | 86.4 | 59.08 | 86.37 | 2.48¶ | 0.83 | 3.03 | 0.02 | 0.18 | ... | . | 0.14 |
| Haw. Agr.†† | 30 | 87.10 | 61.07 | 86.97 | 1.06 | 1.82 | 2.20 | 0.04 | 0.32 | . | . | 0.07 |
| Hakalau | 7 | 85.4 | 65.62 | 85.5 | 0.9 | 0.58 | 2.69 | 0.02 | 0.12 | ... | .. | 0.06 |
| Wailuku | 2 | 86.6 | 64.23 | 86.7 | 1.0 | 3.01 | 2.55 | 0.08 | 0.54 | 0.14 | . | 0.14 |
| Makee | 14 | 84.95 | 58.08 | 84.68 | 0.77 | 1.66 | 2.71 | 0.05 | 0.36 | 0.07 | 0.01 | 0.08 |
| McBryde | 12 | 85.38 | 62.96 | 86.32 | 1.78 | 1.67 | 1.73 | 0.02 | 0.19 | 0.02 | [illegible] | [illegible] |
| Honokaa | 35 | 85.25 | 61.77 | 85.09 | 1.50 | 2.05 | 2.08 | 0.04 | 0.38 | 0.06 | 0.02 | 0.08 |
| Laupahoehoe | 41 | 87.31 | 66.02 | 87.47 | 1.43 | 1.00 | 2.15 | 0.02 | 0.17 | 0.04 | .... | 0.04 |
| Pepeekeo | 19 | 85.2 | 68.31 | 85.4 | 1.5 | 1.12 | 2.20 | 0.02 | 0.20 | 0.06 | . | 0.06 |
| Hamakua* | 15 | 87.33 | 51.05 | 87.29 | .... | .... | .... | . | . | 0.07 | .. | 0.07 |
| Kahuku | 43 | 83.54 | 61.64 | 83.11 | 1.87 | 1.39 | 2.75 | 0.04 | 0.32 | 0.06 | . | 0.06 |
| Paauhau†† | 24 | 85.58 | 67.22 | 85.75 | 1.81¶ | 0.59 | 2.58 | 0.01 | 0.13 | 0.05 | 0.01 | 0.06 |
| Honomu | 37 | 85.6 | 70.22 | 86.7 | 2.6 | 1.20 | 2.55 | [illegible] | 0.24 | .... | ... | 0.06 |
| Koloa | 38 | 83.3 | 61.85 | 83.8 | 2.0 | 2.86 | 3.01 | 0.09 | 0.70 | 0.05 | 0.04 | 0.09 |
| Hutchinson†† | 31 | 86.19 | 67.67 | 86.33 | 1.46 | 3.00 | 2.24 | 0.07 | 0.55 | 0.07 | 0.01 | 0.08 |
| Waiakea | 3 | 85.79 | 51.45 | 85.83 | 0.73¶ | 2.99 | 2.76 | 0.08 | 0.65 | | . | 0.07 |
| Hawi | 26 | 86.6 | 56.42 | 86.9 | 1.2 | 2.38 | 2.58 | 0.06 | 0.49 | 0.10 | ... | 0.10 |
| Kaiwiki | 32 | 86.97 | 61.07 | 86.47 | 0.89¶ | 2.77 | 2.08 | 0.07 | 0.58 | 0.05 | ... | 0.05 |
| Waianae | 9 | 83.65 | 63.15 | 83.14 | 1.83 | 4.26 | 2.42 | 0.08 | 0.57 | 0.04 | 0.01 | 0.05 |
| Kohala | 40 | 86.70 | 58.95 | 86.97 | 1.08 | 3.05 | 4.03 | 0.12 | 0.98 | 0.11 | ... | 0.11 |
| Kilauea†† | 23 | 81.6 | 58.57 | 81.8 | 1.3 | 5.05 | 2.75 | 0.14 | 1.18 | 0.07 | . | 0.07 |
| Kaeleku | 47 | 84.94 | 53.31 | 84.79 | 1.2¶ | 4.27 | 2.12 | 0.09 | 0.75 | .. | . | 0.06 |
| Waimanalo | 1 | 82.53 | 62.28 | 82.21 | 1.31 | 2.08 | 3.22 | 0.07 | 0.54 | 0.10 | ... | 0.10 |
| Union Mill | 11 | 85.6 | 56.4 | 85.8 | 2.5 | 3.47 | 3.69 | 0.13 | 1.06 | 0.07 | 0.01 | 0.08 |
| Halawa | 29 | 84.66 | 56.57 | 84.85 | 1.13¶ | 5.10 | 3.28 | 0.17 | 1.45 | 0.08 | . | 0.08 |
| Waimea | 4 | 85.08 | 62.65 | 85.59 | 1.56¶ | 2.53 | 2.39 | 0.06 | 0.46 | 0.06 | 0.01 | 0.07 |
| Olowalu | 18 | 82.3 | 60.98 | 83.1 | 1.0 | 2.62 | 2.61 | 0.07 | 0.53 | 0.11 | 0.03 | 0.14 |
| Niulii | 39 | 83.54 | 55.44 | 83.53 | 0.33 | 3.56 | 2.14 | 0.08 | 0.70 | ... | . | 0.07 |
| True Average, 1925 | 1925 | 86.15 | 63.65 | 86.27 | 1.07 | 2.28 | 2.23 | 0.05 | 0.38 | .. | | 0.079 |
| " " 1924 | 1924 | 86.18 | 63.32 | 86.32 | 1.27 | 2.26 | 2.16 | 0.05 | 0.37 | ... | ... | 0.086 |
| " " 1923 | 1923 | 85.37 | 63.26 | 85.65 | 1.38 | 2.31 | 2.22 | 0.05 | 0.40 | ... | ... | 0.087 |
| " " 1922 | 1922 | 84.74 | 63.37 | 84.96 | 1.23 | 2.57 | 2.65 | 0.07 | 0.53 | .... | .... | 0.084 |
| " " 1921 | 1921 | 83.74 | 62.09 | 83.90 | 1.13 | 1.66 | 2.58 | 0.04 | 0.33 | .... | .... | 0.074 |
| " " 1920 | 1920 | 85.03 | 61.34 | 85.20 | 1.33 | 1.65 | 2.63 | 0.04 | 0.31 | .... | .... | 0.071 |
| " " 1919 | 1919 | 85.46 | 62.42 | 85.70 | 1.41 | 1.34 | 2.32 | 0.03 | 0.22 | .... | .... | 0.076 |
| " " 1918 | 1918 | 85.36 | 61.66 | 85.78 | 1.79 | 1.48 | 2.36 | 0.03 | 0.26 | .... | ... | 0.072 |
| " " 1917 | 1917 | 86.08 | 62.28 | 86.36 | 1.48 | 1.52 | 2.28 | 0.03 | 0.25 | .... | .... | 0.063 |
| " " 1916 | 1916 | .... | 62.73 | 86.18 | 1.59 | 1.82 | 2.20 | 0.04 | 0.30 | .... | .... | 0.06 |

| Factory | Factory No. | COMMERCIAL SUGAR Polarization | COMMERCIAL SUGAR % Moisture | COMMERCIAL SUGAR Weight per 100 cane | COMMERCIAL SUGAR Pol. per 100 cane | COMMERCIAL SUGAR Pol. per 100 pol. of cane | COMMERCIAL SUGAR Pol. per 100 pol. of juice | COMMERCIAL SUGAR Total weight in thousand tons |
|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co.** | 6 | 96.84 | 0.94 | 14.17 | [illegible] | [illegible] | 95.23 | [illegible] |
| Oahu | 20 | 97.60* | 0.64 | 12.85 | 12.74 | [illegible] | 92.23 | 64 |
| Ewa | 5 | 97.04 | 0.72 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Waialua | 17 | 97.44 | 0.61 | 12.56 | [illegible] | [illegible] | [illegible] | [illegible] |
| Pioneer | 10 | 97.70 | 0.70 | 12.71 | [illegible] | [illegible] | 92.10 | [illegible] |
| Olaa | 36 | 97.67 | 0.61 | 11.44 | 11.18 | 87 | 90.21 | [illegible] |
| Haw. Sug. | 16 | 97.75* | 0.63 | 14.07 | 13.75 | [illegible] | 93.12 | [illegible] |
| Maui Agr.** | 21 | 97.85* | 0.57 | [illegible] | [illegible] | [illegible] | 91.45 | [illegible] |
| Lihue | 27 | 97.27 | 0.73 | 11.45 | 11.14 | [illegible] | 90.98 | [illegible] |
| Onomea†† | 34 | [illegible] | 0.73 | 11.48 | 11.18 | [illegible] | 92.86 | [illegible] |
| Hilo | 33 | 97.27 | 0.91 | [illegible] | [illegible] | [illegible] | 92.41 | [illegible] |
| Kekaha | 25 | 96.69 | 0.88 | [illegible] | 12.19 | [illegible] | 90.48 | [illegible] |
| Honolulu | 13 | . | | ... | | .. | .. | [illegible] |
| Haw. Agr.†† | 30 | 97.01 | 0.82 | [illegible] | 10.74 | [illegible] | 88.39 | [illegible] |
| Hakalau | 7 | 96.74 | 0.86 | [illegible] | [illegible] | [illegible] | 93.06 | 18 |
| Wailuku | 2 | 97.36 | 0.67 | [illegible] | [illegible] | [illegible] | 92.23 | 18 |
| Makee | 14 | 97.28 | 0.89 | [illegible] | [illegible] | [illegible] | 89.59 | [illegible] |
| McBryde | 12 | 96.78 | [illegible] | [illegible] | [illegible] | [illegible] | 91.72 | [illegible] |
| Honokaa | 35 | 96.74 | 0.81 | [illegible] | [illegible] | [illegible] | 91.43 | [illegible] |
| Laupahoehoe | 41 | 96.93 | 0.93 | 11.72 | [illegible] | [illegible] | 91.70 | 15 |
| Pepeekeo | 19 | 97.36 | 0.74 | 11.70 | [illegible] | [illegible] | 93.40 | 14 |
| Hamakua* | 15 | [illegible] | 0.84 | 11.73 | [illegible] | [illegible] | 91.15 | 14 |
| Kahuku | 43 | 97.70 | [illegible] | [illegible] | [illegible] | [illegible] | 92.80 | [illegible] |
| Paauhau†† | 24 | 96.89 | 0.51 | 10.97 | 10.61 | [illegible] | 91.96 | [illegible] |
| Honomu | 37 | 97.72 | 0.44 | 11.74 | 11.47 | [illegible] | 92.59 | 9 |
| Koloa | 38 | 97.06 | 0.82 | 11.16 | [illegible] | [illegible] | 90.44 | 11 |
| Hutchinson†† | 31 | 97.14 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 11§ |
| Waiakea | 3 | 96.94 | 0.89 | [illegible] | [illegible] | [illegible] | [illegible] | 11 |
| Hawi | 26 | 96.58 | 0.91 | [illegible] | [illegible] | [illegible] | 86.47 | 11 |
| Kaiwiki | 32 | 96.84 | 0.86 | 11.46 | 11.10 | [illegible] | 91.02 | 8 |
| Waianae | 9 | 96.72 | 0.72 | 11.86 | 11.47 | [illegible] | 84.72 | [illegible] |
| Kohala | 40 | 97.08 | 0.72 | [illegible] | [illegible] | [illegible] | 91.11 | 7 |
| Kilauea†† | 23 | 97.18 | 0.79 | 10.19 | [illegible] | [illegible] | 86.76 | [illegible] |
| Kaeleku | 47 | 96.65 | ... | 10.77 | [illegible] | [illegible] | [illegible] | [illegible] |
| Waimanalo | 1 | 96.29 | 0.84 | [illegible] | 11.17 | [illegible] | [illegible] | 8 |
| Union Mill | 11 | [illegible] | 1.16 | 10.56 | 10.17 | [illegible] | [illegible] | [illegible] |
| Halawa | 29 | 96.76 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Waimea | 4 | 96.53 | .. | 11.88 | [illegible] | [illegible] | [illegible] | [illegible] |
| Olowalu | 18 | 96.34 | [illegible] | 11.05 | 10.64 | [illegible] | [illegible] | [illegible] |
| Niulii | 39 | 96.42 | 1.04 | 8.78 | 8.47 | [illegible] | 85.81 | 3 |
| True Average, 1925 | 1925 | 97.22 | 0.75 | 12.10 | 11.76 | [illegible] | 91.59 | 767 |
| " " 1924 | 1924 | 97.18 | 0.75 | 12.11 | 11.77 | [illegible] | 91.39 | 696 |
| " " 1923 | 1923 | 96.90 | 0.83 | [illegible] | [illegible] | [illegible] | 91.28 | [illegible] |
| " " 1922 | 1922 | 96.88 | 0.87 | 11.61 | [illegible] | [illegible] | [illegible] | [illegible] |
| " " 1921 | 1921 | 96.75 | 0.92 | 11.62 | 11.24 | [illegible] | [illegible] | [illegible] |
| " " 1920 | 1920 | [illegible] | 0.97 | [illegible] | 11.87 | [illegible] | [illegible] | 747 |
| " " 1919 | 1919 | [illegible] | 0.96 | 12.59 | [illegible] | [illegible] | [illegible] | [illegible] |
| " " 1918 | 1918 | 96.53 | 0.94 | 11.75 | [illegible] | 87.91 | 90.37 | 557 |
| " " 1917 | 1917 | 96.87 | 0.57 | 12.45 | [illegible] | [illegible] | [illegible] | .. |
| " " 1916 | 1916 | 96.31 | 1.06 | 12.25 | 11.86 | [illegible] | 90.84 | .. |

| Factory | Factory No. | FINAL MOLASSES Weight per 100 cane | FINAL MOLASSES Sucrose per 100 cane | FINAL MOLASSES Sucrose per 100 pol. of cane | FINAL MOLASSES Sucrose per 100 pol. of juice | FINAL MOLASSES Gravity solids | FINAL MOLASSES Gravity purity | FINAL MOLASSES True purity | OTHER KNOWN LOSSES Pol. per 100 cane | OTHER KNOWN LOSSES Pol. per 100 pol. of cane | UNDETERMINED LOSSES Pol. per 100 cane | UNDETERMINED LOSSES Pol. per 100 pol. of cane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co.** | 6 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Oahu | 20 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Ewa | 5 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Waialua | 17 | 2.71 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Pioneer | 10 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Olaa | 36 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Haw. Sug. | 16 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Maui Agr.** | 21 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Lihue | 27 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Onomea†† | 34 | [illegible] | 0.81 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Hilo | 33 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Kekaha | 25 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Honolulu | 13 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Haw. Agr.†† | 30 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Hakalau | 7 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Wailuku | 2 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Makee | 14 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| McBryde | 12 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Honokaa | 35 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Laupahoehoe | 41 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Pepeekeo | 19 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Hamakua* | 15 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Kahuku | 43 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Paauhau†† | 24 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Honomu | 37 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Koloa | 38 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Hutchinson†† | 31 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Waiakea | 3 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Hawi | 26 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Kaiwiki | 32 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Waianae | 9 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Kohala | 40 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Kilauea†† | 23 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Kaeleku | 47 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Waimanalo | 1 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Union Mill | 11 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Halawa | 29 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Waimea | 4 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Olowalu | 18 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Niulii | 39 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| True Average, 1925 | 1925 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| " " 1924 | 1924 | [illegible] | [illegible] | 7.41 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| " " 1923 | 1923 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| " " 1922 | 1922 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| " " 1921 | 1921 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| " " 1920 | 1920 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| " " 1919 | 1919 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| " " 1918 | 1918 | 3.04 | 1.04 | 7.96 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| " " 1917 | 1917 | 3.07 | 1.07 | 7.68 | [illegible] | [illegible] | 40.03 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| " " 1916 | 1916 | 2.90 | 0.98 | 7.41 | [illegible] | [illegible] | 39.25 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

* Sucrose.
† Refined sugar.
‡ For one mill only.
¶ Probably influenced by low grade sugar in syrup.
§ 1925 crop unfinished.
** Petree process.
†† Balance of 1924 crop included.

# CANE MILL DATA, SEASON OF 1925

**Milling Plant and Revolving Knives**

| Factory | Factory No. | MILLING PLANT (Sizes in Inches) | Revolving Knives, First Set: Number | First Set: Distance Apart Inches | First Set: Distance from Conveyor Inches | First Set: Revolutions per Minute | Second Set: Number | Second Set: Distance Apart Inches | Second Set: Distance from Conveyor Inches | Second Set: Revolutions per Minute |
|---|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co. | 6 | K(2),2RC34x78,S72,12RM34x78 | 28 | 9 3/4 | 24 | 1200 | 56 | 5 | 16 | 1200 |
| " " | 6 | K(2),2RC34x78,S72,12RM34x78 | 28 | 9 3/4 | 24 | 1200 | 56 | 5 | 16 | 1200 |
| Oahu | 20 | K,2RC34x78,S72,12RM34x78 | 26 | 5 | 19 | 490 | .. | .... | .... | .... |
| " | 20 | K,2RC34x78,S72,12RM34x78 | 28 | 4 1/2 | 18 | 690 | .. | .... | .... | .... |
| Ewa | 5 | K(2),2RC33x78,18RM34x78 | 72 | 2 | 16 | 580 | 72 | 2 | 2 1/2 | 580 |
| Waialua | 17 | K(2),2RC33x78,12RM34x78 | 24 | 5 1/2 | 12 | 650 | 72 | 1 7/8 | 2 1/2 | 650 |
| Pioneer | 10 | K,2RC34x72,S72,15RM34x72 | 27 | 2 1/4 | 16 | 690 | .. | .... | .... | .... |
| Olaa | 36 | K,S72,12RM34x78 | 36 | 1 3/4 | 4 1/4 | 420 | .. | .... | .... | .... |
| Haw. Sug. | 16 | K,2RC28x72,S72,12RM34x78 | 32 | 4 | 15 | 450 | .. | .... | .... | .... |
| Maui Agr. | 21 | K(2),3RC34x66,18RM34x66 | 72 | 7/8 | 10 | 450 | 72 | 7/8 | 7/8 | 520 |
| Lihue | 27 | K,2RC34x78,S72,12RM34x78 | 10 | 7 | 10 | 350 | .. | .... | .... | .... |
| Onomea | 34 | 2RC28x60,S54,12RM32x66 | .. | ..... | .... | .... | .. | .... | .... | .... |
| Hilo | 33 | K,2RC24x60,12RM32x66 | 10 | 6 | 10 | 200 | .. | .... | .... | .... |
| Kekaha | 25 | 2RC24x54,15RM32x60 | .. | ..... | .... | .... | .. | .... | .... | .... |
| Honolulu | 13 | K(2),S54,2RC32x78,9RM34x78 | 24 | 6 | 18 | 450 | 24 | 6 | 4 | 450 |
| Haw. Agr. | 30 | 3RC32x60,12RM32x66 | .. | ..... | .... | .... | .. | .... | .... | .... |
| Hakalau | 7 | 2RC24x54,12RM9-32x60,3-32x66 | .. | ..... | .... | .... | .. | .... | .... | .... |
| Wailuku | 2 | K,2RC28x72,12RM34x78 | 10 | 6 | 18 | 400 | .. | .... | .... | .... |
| Makee | 14 | K,2RC34x72,S72,9RM34x72 | 12 | 6 | 30 | 450 | .. | .... | .... | .... |
| McBryde | 12 | K,2RC34x72,S72,9RM34x84 | 24 | 8 | 16 | 400 | .. | .... | .... | .... |
| Honokaa | 35 | K(2),2RC30x66,12RM32x66 | 98 | 1 1/2 | 19 | 390 | 84 | 17/32 | 10 | 470 |
| Laupahoehoe | 41 | K,2RC30x54,9RM32x60 | 16 | 3 3/4 | 2 | 450 | .. | .... | .... | .... |
| Pepeekeo | 19 | 2RC24x54,9RM32x60 | .. | ..... | .... | .... | .. | .... | .... | .... |
| Hamakua | 15 | K,2RC30x60,12RM32x60 | 28 | 4 | 1 1/2 | 400 | .. | .... | .... | .... |
| Kahuku | 43 | K,2RC26x60,S54,9RM34x72 | 14 | 4 | 24 | 350 | .. | .... | .... | .... |
| Paauhau | 24 | 2RC26x60,12RM32x66 | .. | ..... | .... | .... | .. | .... | .... | .... |
| Honomu | 37 | 3RC33x60,9RM32x60 | .. | ..... | .... | .... | .. | .... | .... | .... |
| Koloa | 38 | K,2RC27x60,12RM32x66 | 24 | 5 | 9 | 300 | .. | .... | .... | .... |
| Hutchinson | 31 | 2RC30x60,9RM32x60 | .. | ..... | .... | .... | .. | .... | .... | .... |
| Waiakea | 3 | K,2RC27x60,9RM32x60 | 38 | 6 | 4 1/2 | 380 | .. | .... | .... | .... |
| Hawi | 26 | K(2),3RC26x48,12RM3-26x48,9-30x54 | 14 | 3 1/4 | 2 1/2 | 485 | 8 | 5 | 6 | 525 |
| Kaiwiki | 32 | K,2RC24x60,9RM32x60 | 18 | 3 | 2 | 350 | .. | .... | .... | .... |
| Waianae | 9 | K(2),12RM9-30x60,3-32x60 | 19 | 3 | 10 | 275 | 19 | 3 | 4 | 525 |
| Kohala | 40 | K(2),3RC30x60,9RM32x60 | 12 | 4 | 18 | 375 | 38 | 1 1/2 | 1 | 400 |
| Kilauea | 23 | K,S,3RC31x60,9RM32x60 | 10 | 6 | 2 | 250 | .. | .... | .... | .... |
| Kaeleku | 47 | K,2RC24x54,9RM32x60 | 9 | 6 | 8 | 250 | .. | .... | .... | .... |
| Waimanalo | 1 | K,3RC32x54,9RM30x54 | 28 | 1 7/8 | 4 | 514 | .. | .... | .... | .... |
| Union Mill | 11 | K,9RM30x60 | 16 | 4 | 6 | 400 | .. | .... | .... | .... |
| Halawa | 29 | K,2RC30x60,6RM26x50 | 20 | 5 | 1 1/2 | 375 | .. | .... | .... | .... |
| Waimea | 4 | 2RC24x48,12RM26x42 | .. | ..... | .... | .... | .. | .... | .... | .... |
| Olowalu | 18 | K,3RC28x48,9RM27x48 | 16 | 4 | 1 1/2 | 400 | .. | .... | .... | .... |
| Niulii | 39 | K,9RM30x54 | 9 | 6 | 4 | 500 | .. | .... | .... | .... |

**Mill Openings**

| Factory | Factory No. | Crushers | 1st Mill Front | 1st Mill Back | 2nd Mill Front | 2nd Mill Back | 3rd Mill Front | 3rd Mill Back | 4th Mill Front | 4th Mill Back | 5th Mill Front | 5th Mill Back |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co. | 6 | 1/16 | 7/16 | 1/16 | 5/16 | 1/32 | 5/16 | 0 | 7/16 | 0 | ... | ... |
| " " | 6 | 1/16 | 7/16 | 1/16 | 5/16 | 1/32 | 5/16 | 0 | 7/16 | 0 | ... | ... |
| Oahu | 20 | 1/4 | 3/8 | 0 | 5/8 | 0 | 1/2 | 0 | 5/16 | 0 | ... | ... |
| " | 20 | 1/4 | 3/8 | 0 | 5/8 | 0 | 1/2 | 0 | 3/8 | 0 | ... | ... |
| Ewa | 5 | 3/8 | 1 | 3/16 | 3/4 | 1/8 | 3/4 | 1/8 | 5/8 | 1/8 | 1/2 | 0 † |
| Waialua | 17 | 1 | 1/4 | 0 | 3/16 | 0 | 1/4 | 0 | 1/4 | 0 | ... | ... |
| Pioneer | 10 | 3/16 | 1/2 | 1/16 | 7/16 | 1/16 | 7/16 | 1/16 | 7/16 | 0 | 7/16 | 0 |
| Olaa | 36 | .... | 5/8 | 3/16 | 5/8 | 1/8 | 3/8 | 0 | 1/4 | 0 | ... | ... |
| Haw. Sug. | 16 | 1/4 | 9/16 | 1/16 | 3/8 | 0 | 5/16 | 0 | 1/4 | 0 | ... | ... |
| Maui Agr. | 21 | 7/16x1/16 | 13/16 | 0 | 9/16 | 0 | 1/4 | 0 | 5/8 | 3/16 | 1/2 | 0 ‡ |
| Lihue | 27 | 1/16 | 5/8 | 1/16 | 7/16 | 0 | 5/16 | 0 | 1/4 | 0 | ... | ... |
| Onomea | 34 | 5/16 | 1/2 | 1/16 | 3/8 | 0 | 3/8 | 0 | 1/4 | 0 | ... | ... |
| Hilo | 33 | 1/2 | 3/4 | 1/32 | 1/4 | 0 | 3/16 | 0 | 3/8 | 0 | ... | ... |
| Kekaha | 25 | 7/8 | 7/8 | 1/4 | 11/16 | 1/8 | 5/8 | 1/16 | 1/2 | 1/16 | 1/2 | 1/32 |
| Honolulu | 13 | 3/16 | 3/4 | 1/2 | 3/8 | 0 | 3/8 | 0 | ... | ... | ... | ... |
| Haw. Agr. | 30 | 1x5/8 | 3/4 | 1/8 | 5/8 | 1/16 | 9/16 | 0 | 5/16 | 0 | ... | ... |
| Hakalau | 7 | 1/4 | 3/4 | 0 | 1/4 | 0 | 1/8 | 0 | 1/4 | 0 | ... | ... |
| Wailuku | 2 | 1/16 | 3/16 | 0 | 3/8 | 0 | 5/16 | 0 | 3/16 | 0 | ... | ... |
| Makee | 14 | 0 | 7/16 | 0 | 3/8 | 0 | 3/8 | 0 | ... | ... | ... | ... |
| McBryde | 12 | 1/4 | 7/16 | 0 | 3/8 | 0 | 1/4 | 0 | ... | ... | ... | ... |
| Honokaa | 35 | 3/4 | 5/8 | 3/16 | 7/16 | 1/8 | 3/8 | 1/16 | 5/16 | 1/32 | ... | ... |
| Laupahoehoe | 41 | 7/16 | 3/8 | 0 | 1/4 | 0 | 1/8 | 0 | ... | ... | ... | ... |
| Pepeekeo | 19 | 0 | 1/2 | 0 | 3/32 | 0 | 3/32 | 0 | ... | ... | ... | ... |
| Hamakua | 15 | 1/2 | 1/2 | 0 | 3/8 | 0 | 1/4 | 0 | 3/16 | 0 | ... | ... |
| Kahuku | 43 | 3/8 | 3/16 | 0 | 1/8 | 0 | 3/16 | 0 | ... | ... | ... | ... |
| Paauhau | 24 | 0 | 3/8 | 0 | 1/4 | 0 | 3/16 | 0 | 1/8 | 0 | ... | ... |
| Honomu | 37 | 1/2x0 | 3/8 | 0 | 3/16 | 0 | 3/16 | 0 | ... | ... | ... | ... |
| Koloa | 38 | 1/8 | 3/4 | 1/16 | 1/2 | 1/32 | 3/8 | 0 | 5/16 | 0 | ... | ... |
| Hutchinson | 31 | 1/2 | 3/8 | 0 | 1/4 | 0 | 1/8 | 0 | ... | ... | ... | ... |
| Waiakea | 3 | 0 | 9/16 | 0 | 1/4 | 0 | 3/16 | 0 | ... | ... | ... | ... |
| Hawi | 26 | 3/4x5/16 | 3/8 | 1/16 | 3/16 | 0 | 1/16 | 0 | 1/16 | 0 | ... | ... |
| Kaiwiki | 32 | 3/16 | 3/8 | 0 | 1/4 | 0 | 1/4 | 0 | ... | ... | ... | ... |
| Waianae | 9 | .... | 1/2 | 1/4 | 3/8 | 0 | 7/16 | 0 | 5/16 | 0 | ... | ... |
| Kohala | 40 | 3/4x3/8 | 3/8 | 0 | 1/4 | 0 | 1/8 | 0 | ... | ... | ... | ... |
| Kilauea | 23 | 5/16x1/8 | 5/16 | 0 | 3/16 | 0 | 1/8 | 0 | ... | ... | ... | ... |
| Kaeleku | 47 | 0 | 7/8 | 0 | 1/4 | 0 | 1/8 | 0 | ... | ... | ... | ... |
| Waimanalo | 1 | 3/4x1/8 | 1/4 | 0 | 1/4 | 0 | 1/4 | 0 | ... | ... | ... | ... |
| Union Mill | 11 | .... | 5/8 | 1/8 | 1/4 | 0 | 1/4 | 0 | ... | ... | ... | ... |
| Halawa | 29 | 3/8 | 5/16 | 0 | 1/8 | 0 | ... | ... | ... | ... | ... | ... |
| Waimea | 4 | 0 | 1/2 | 1/8 | 7/16 | 0 | 1/4 | 0 | 1/4 | 0 | ... | ... |
| Olowalu | 18 | 3/8x1/16 | 1/4 | 0 | 1/4 | 0 | 1/4 | 0 | ... | ... | ... | ... |
| Niulii | 39 | .... | 5/8 | 1/8 | 1/4 | 1/32 | 1/8 | 0 | ... | ... | ... | ... |

**Returner Bar — Distance from Top Roller — Inches**

| Factory | Factory No. | Crusher Toe | Crusher Center | Crusher Heel | 1st Mill Toe | 1st Mill Center | 1st Mill Heel | 2nd Mill Toe | 2nd Mill Center | 2nd Mill Heel | 3rd Mill Toe | 3rd Mill Center | 3rd Mill Heel | 4th Mill Toe | 4th Mill Center | 4th Mill Heel | 5th Mill Toe | 5th Mill Center | 5th Mill Heel |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co. | 6 | ..... | ..... | ..... | 1 1/4 | 1 3/4 | 2 1/4 | 1 1/4 | 1 3/4 | 2 1/4 | 1 1/4 | 1 3/4 | 2 1/4 | 1 1/4 | 1 3/4 | 2 1/4 | .... | .... | .... |
| " " | 6 | ..... | ..... | ..... | 1 1/4 | 1 3/4 | 2 1/4 | 1 1/4 | 1 3/4 | 2 1/4 | 1 1/4 | 1 3/4 | 2 1/2 | 1 1/4 | 1 3/4 | 2 1/2 | .... | .... | .... |
| Oahu | 20 | ..... | ..... | ..... | 1 3/16 | 1 1/2 | 1 3/4 | 1 5/16 | 1 9/16 | 1 3/4 | 1 5/16 | 1 7/16 | 1 9/16 | 1 3/8 | 1 7/16 | 1 9/16 | .... | .... | .... |
| " | 20 | ..... | ..... | ..... | 1 5/16 | 1 7/16 | 1 11/16 | 1 5/8 | 1 11/16 | 1 3/4 | 1 1/16 | 1 1/4 | 1 5/8 | 1 1/8 | 1 3/8 | 1 11/16 | .... | .... | .... |
| Ewa | 5 | ..... | ..... | ..... | 1 1/2 | 1 3/4 | 2 | 1 1/2 | 1 3/4 | 2 | 1 1/2 | 1 3/4 | 2 | 1 3/4 | 1 7/8 | 2 | 1 1/2 | 1 3/4 | 2 |
| Waialua | 17 | ..... | ..... | ..... | 1 1/2 | 1 5/8 | 1 7/8 | 1 1/2 | 1 5/8 | 1 7/8 | 1 7/8 | 2 | 2 1/4 | 1 7/8 | 2 | 2 1/4 | .... | .... | .... |
| Pioneer | 10 | ..... | ..... | ..... | 1 3/8 | 1 5/8 | 1 3/4 | 1 1/4 | 1 1/2 | 1 5/8 | 1 1/4 | 1 1/2 | 1 5/8 | 1 1/4 | 1 1/2 | 1 5/8 | 1 1/4 | 1 1/2 | 1 5/8 |
| Olaa | 36 | ..... | ..... | ..... | 1 1/2 | 1 3/4 | 2 1/4 | 1 1/4 | 1 1/2 | 2 | 1 1/8 | 1 3/8 | 1 7/8 | 1 | 1 1/4 | 1 3/4 | .... | .... | .... |
| Haw. Sug. | 16 | ..... | ..... | ..... | 1 1/4 | 1 1/2 | 1 3/4 | 1 1/4 | 1 1/2 | 1 3/4 | 1 1/4 | 1 1/2 | 1 3/4 | 1 1/8 | 1 3/8 | 1 5/8 | .... | .... | .... |
| Maui Agr. | 21 | .... | 1 1/2 | ..... | ..... | 1 1/2 | .... | ..... | 1 1/2 | ..... | ..... | 1 3/8 | ..... | ..... | 1 1/2 | ..... | .... | 1 1/2 | .... |
| Lihue | 27 | ..... | ..... | ..... | 1 | 1 1/2 | 2 | 1 | 1 1/2 | 2 | 1 | 1 1/2 | 2 | 1 | 1 1/2 | 2 | .... | .... | .... |
| Onomea | 34 | ..... | ..... | ..... | 1 1/8 | 1 3/8 | 1 1/2 | 1 | 1 1/4 | 1 1/2 | 1 | 1 1/4 | 1 1/2 | 7/8 | 1 | 1 1/4 | .... | .... | .... |
| Hilo | 33 | ..... | ..... | ..... | 1 3/16 | 1 5/16 | 1 9/16 | 1 | 1 1/4 | 1 9/16 | 3/4 | 1 3/16 | 1 3/8 | 3/4 | 1 | 1 3/8 | .... | .... | .... |
| Kekaha | 25 | ..... | ..... | ..... | ..... | 2 | ..... | ..... | 2 | ..... | ..... | 1 3/4 | ..... | ..... | 1 3/4 | ..... | .... | 1 1/2 | .... |
| Honolulu | 13 | ..... | ..... | ..... | 2 | 2 1/8 | 2 1/4 | 2 | 2 1/8 | 2 1/4 | 2 | 2 1/8 | 2 1/4 | ..... | ..... | ..... | .... | .... | .... |
| Haw. Agr. | 30 | 1 1/2 | 1 5/8 | 1 3/4 | 1 1/2 | 1 1/2 | 1 3/4 | 1 1/2 | 1 3/4 | 1 13/16 | 1 | 1 1/4 | 1 1/4 | 1 | 1 1/4 | 1 1/2 | .... | .... | .... |
| Hakalau | 7 | ..... | ..... | ..... | 1 | 1 1/2 | 2 1/4 | 3/8 | 1 | 2 | 3/8 | 3/4 | 1 3/4 | 1/2 | 1 | 2 | .... | .... | .... |
| Wailuku | 2 | ..... | ..... | ..... | 1 1/4 | 1 1/2 | 1 3/4 | 1 1/4 | 1 1/2 | 1 3/4 | 1 1/4 | 1 1/2 | 1 3/4 | 1 1/4 | 1 1/2 | 1 3/4 | .... | .... | .... |
| Makee | 14 | ..... | ..... | ..... | 1 | 1 1/2 | 2 | 1 | 1 1/2 | 2 | 1 | 1 1/2 | 2 | ..... | ..... | ..... | .... | .... | .... |
| McBryde | 12 | ..... | ..... | ..... | 1 1/4 | 1 1/2 | 2 | 1 1/2 | 1 3/4 | 2 | 1 1/2 | 1 3/4 | 2 | ..... | ..... | ..... | .... | .... | .... |
| Honokaa | 35 | ..... | ..... | ..... | 1 1/8 | 1 1/4 | 1 1/2 | 1 1/8 | 1 1/4 | 1 1/2 | 1 | 1 1/8 | 1 1/2 | 1 | 1 1/4 | 1 5/16 | .... | .... | .... |
| Laupahoehoe | 41 | ..... | ..... | ..... | 1 | 1 1/4 | 1 1/2 | 1 | 1 1/8 | 1 3/8 | 1/2 | 1 3/16 | 1 1/4 | ..... | ..... | ..... | .... | .... | .... |
| Pepeekeo | 19 | ..... | ..... | ..... | 1 | 1 1/8 | 1 1/4 | 3/4 | 1 1/16 | 1 1/8 | 1 5/16 | 1 1/8 | 2 1/8 | ..... | ..... | ..... | .... | .... | .... |
| Hamakua | 15 | ..... | ..... | ..... | 1 1/4 | 1 1/2 | 1 3/8 | 1 1/4 | 1 1/2 | 1 3/4 | 1 1/8 | 1 3/8 | 1 5/8 | 1 | 1 1/4 | 1 1/2 | .... | .... | .... |
| Kahuku | 43 | ..... | ..... | ..... | 3/4 | 1 | 1 3/4 | 3/8 | 1 | 1 1/2 | 1/2 | 3/4 | 1 3/8 | ..... | ..... | ..... | .... | .... | .... |
| Paauhau | 24 | ..... | ..... | ..... | 1 9/16 | 1 3/4 | 2 3/16 | 1 1/8 | 1 7/16 | 2 1/8 | 1 1/32 | 1 5/16 | 1 13/16 | 1 1/2 | 1 11/16 | 2 1/2 | .... | .... | .... |
| Honomu | 37 | 3/8 | 1/2 | 1 | 3/4 | 1 | 1 1/16 | 5/8 | 7/8 | 1 1/16 | 3/8 | 3/4 | 1 1/16 | ..... | ..... | ..... | .... | .... | .... |
| Koloa | 38 | ..... | ..... | ..... | 1 1/4 | 1 3/4 | 2 | 1 1/4 | 1 1/2 | 1 3/4 | 1 1/4 | 1 1/2 | 1 3/4 | 1 1/4 | 1 1/2 | 1 3/4 | .... | .... | .... |
| Hutchinson | 31 | ..... | ..... | ..... | 7/8 | 1 1/8 | 1 3/8 | 7/8 | 1 1/8 | 1 3/8 | 7/8 | 1 1/8 | 1 3/8 | ..... | ..... | ..... | .... | .... | .... |
| Waiakea | 3 | ..... | ..... | ..... | 1 1/4 | 1 5/16 | 1 3/4 | 1 1/16 | 1 3/16 | 1 1/2 | 7/8 | 15/16 | 1 5/16 | ..... | ..... | ..... | .... | .... | .... |
| Hawi | 26 | 1 11/16 | 1 1/4 | 1 3/8 | 1 | 1 1/4 | 1 1/2 | 7/8 | 1 | 1 3/8 | 3/4 | 1 | 1 1/4 | 3/4 | 1 | 1 1/4 | .... | .... | .... |
| Kaiwiki | 32 | ..... | ..... | ..... | 7/8 | 1 1/8 | 1 3/8 | 1 1/8 | 1 1/4 | 1 1/2 | 1 | 1 1/4 | 1 1/8 | ..... | ..... | ..... | .... | .... | .... |
| Waianae | 9 | ..... | ..... | ..... | 1 | 1 1/2 | 2 | 7/8 | 1 1/8 | 1 3/4 | 7/8 | 1 1/8 | 1 3/4 | 7/8 | 1 | 1 1/2 | .... | .... | .... |
| Kohala | 40 | 1 1/2 | 1 3/4 | 2 1/4 | 3/8 | 1 1/8 | 1 5/8 | 1/2 | 1 1/8 | 1 3/4 | 3/8 | 1 | 1 3/8 | ..... | ..... | ..... | .... | .... | .... |
| Kilauea | 23 | 1 3/4 | 2 | 2 1/4 | 1 1/8 | 1 1/2 | 1 3/4 | 1 1/8 | 1 1/2 | 1 7/8 | 1 1/8 | 1 1/2 | 2 | ..... | ..... | ..... | .... | .... | .... |
| Kaeleku | 47 | ..... | ..... | ..... | 1 1/4 | 1 1/2 | 1 3/4 | 1 | 1 1/4 | 1 1/2 | 3/4 | 1 | 1 1/4 | ..... | ..... | ..... | .... | .... | .... |
| Waimanalo | 1 | 5/8 | 7/8 | 1 1/8 | 1 | 1 1/4 | 1 1/2 | 1 | 1 1/4 | 1 1/2 | 1 | 1 1/4 | 1 1/2 | ..... | ..... | ..... | .... | .... | .... |
| Union Mill | 11 | ..... | ..... | ..... | 1 5/8 | 1 3/4 | 1 3/4 | 1 1/4 | 1 3/8 | 1 1/2 | 1 1/4 | 1 3/8 | 1 1/2 | ..... | ..... | ..... | .... | .... | .... |
| Halawa | 29 | ..... | ..... | ..... | 5/8 | 1 | 1 1/2 | 5/8 | 13/16 | 1 1/8 | ..... | ..... | ..... | ..... | ..... | ..... | .... | .... | .... |
| Waimea | 4 | ..... | ..... | ..... | 1 1/4 | 1 1/2 | 1 3/4 | 1 1/4 | 1 1/2 | 1 3/4 | 3/4 | 1 | 1 1/8 | 3/4 | 1 | 1 1/8 | .... | .... | .... |
| Olowalu | 18 | 1/2 | 1 | 1 1/2 | 1 | 1 1/4 | 1 1/2 | 11/16 | 1 | 1 1/2 | 1/2 | 1 | 1 1/2 | ..... | ..... | ..... | .... | .... | .... |
| Niulii | 39 | ..... | ..... | ..... | 2 | 2 1/4 | 3 | 1 1/4 | 1 3/8 | 1 3/4 | 1 1/4 | 1 1/2 | 1 3/4 | ..... | ..... | ..... | .... | .... | .... |

**Returner Bar — Width — Inches, and Distance from Back Roller — Inches**

| Factory | Factory No. | Width 1st Mill | Width 2nd Mill | Width 3rd Mill | Width 4th Mill | Width 5th Mill | Width 6th Mill | Back Roller 1st Mill | Back Roller 2nd Mill | Back Roller 3rd Mill | Back Roller 4th Mill | Back Roller 5th Mill | Back Roller 6th Mill |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co. | 6 | 13 | 12 1/4 | 12 1/4 | 12 1/4 | ...... | ...... | 1/2 | 1/2 | 1/2 | 1/2 | ... | ... |
| " " | 6 | 13 | 12 1/4 | 12 1/4 | 12 1/4 | ...... | ...... | 1/2 | 1/2 | 1/2 | 1/2 | ... | ... |
| Oahu | 20 | 13 5/8 | 13 5/8 | 11 1/4 | 11 1/4 | ...... | ...... | 7/8 | 11/16 | 1 1/8 | 1/2 | ... | ... |
| " | 20 | 14 | 16 | 14 1/4 | 13 | ...... | ...... | 1 1/8 | 1 1/4 | 1 1/4 | 1/2 | ... | ... |
| Ewa | 5 | 13 | 13 | 13 | 13 | 13 | 13 | 7/8 | 3/4 | 5/8 | 3/4 | 3/4 | 3/8 |
| Waialua | 17 | 13 | 11 1/2 | 12 1/2 | 12 | ...... | ...... | 3/4 | 3/4 | 7/8 | 7/8 | ... | ... |
| Pioneer | 10 | 12 3/4 | 12 3/4 | 12 3/4 | 12 3/4 | 12 3/4 | ...... | 9/16 | 9/16 | 9/16 | 9/16 | 9/16 | ... |
| Olaa | 36 | 15 | 14 1/2 | 14 1/2 | 12 | ...... | ...... | 1/2 | 1/2 | 1/2 | 1/2 | ... | ... |
| Haw. Sug. | 16 | 13 1/2 | 13 1/2 | 13 1/2 | 13 1/2 | ...... | ...... | 3/8 | 3/8 | 3/8 | 3/8 | ... | ... |
| Maui Agr. | 21 | ...... | ...... | ...... | ...... | ...... | ...... | 5/16 | 3/4 | 1/2 | 3/4 | 1/2 | 1/2 |
| Lihue | 27 | 13 3/8 | 14 | 14 | 12 1/2 | ...... | ...... | 1/2 | 1/2 | 1/2 | 1/2 | ... | ... |
| Onomea | 34 | 12 | 12 | 12 | 12 | ...... | ...... | 1/2 | 1/2 | 1/2 | 1/2 | ... | ... |
| Hilo | 33 | 11 3/8 | 12 | 12 1/2 | 11 3/4 | ...... | ...... | 1/4 | 3/8 | 3/8 | 1/4 | ... | ... |
| Kekaha | 25 | 13 | 12 | 11 1/2 | 11 1/2 | 11 1/2 | ...... | 3/4 | 1/2 | 1/2 | 1/2 | 1/2 | ... |
| Honolulu | 13 | 12 1/2 | 11 1/4 | 12 | ...... | ...... | ...... | 7/8 | 1/2 | 1/2 | ... | ... | ... |
| Haw. Agr. | 30 | 13 1/4 | 12 7/8 | 12 1/2 | 12 | ...... | ...... | 1/2 | 3/8 | 1/4 | 1/2 | ... | ... |
| Hakalau | 7 | 12 3/8 | 12 1/8 | 12 1/2 | 12 | ...... | ...... | 1/2 | 3/8 | 1/2 | 1/2 | ... | ... |
| Wailuku | 2 | 11 3/4 | 12 1/2 | 14 | 14 1/8 | ...... | ...... | 3/4 | 5/8 | 5/8 | 5/8 | ... | ... |
| Makee | 14 | 13 | 13 | 13 | ...... | ...... | ...... | 1/4 | 1/4 | 1/8 | ... | ... | ... |
| McBryde | 12 | 12 1/2 | 13 | 13 | ...... | ...... | ...... | 1/2 | 1/2 | 3/8 | ... | ... | ... |
| Honokaa | 35 | 10 | 11 | 11 | 11 1/4 | ...... | ...... | 3/4 | 3/4 | 1 | 1 1/4 | ... | ... |
| Laupahoehoe | 41 | 10 7/8 | 10 7/8 | 12 3/8 | ...... | ...... | ...... | 5/8 | 13/16 | 1 1/8 | ... | ... | ... |
| Pepeekeo | 19 | 14 1/2 | 13 1/2 | 12 1/8 | ...... | ...... | ...... | 1/2 | 1/2 | 1/2 | ... | ... | ... |
| Hamakua | 15 | 12 1/2 | 12 1/2 | 12 1/4 | 11 1/2 | ...... | ...... | 1/2 | 1/2 | 1/2 | 1/2 | ... | ... |
| Kahuku | 43 | 14 | 15 | 12 1/4 | ...... | ...... | ...... | 1/4 | 1/4 | 1/4 | ... | ... | ... |
| Paauhau | 24 | 11 | 12 | 12 1/2 | 11 | ...... | ...... | 3/8 | 3/8 | 3/4 | 1/2 | ... | ... |
| Honomu | 37 | 12 | 12 1/4 | 12 1/2 | ...... | ...... | ...... | 3/4 | 3/4 | 13/16 | ... | ... | ... |
| Koloa | 38 | 12 | 10 1/2 | 10 | 10 | ...... | ...... | 3/8 | 3/8 | 1/2 | 1/2 | ... | ... |
| Hutchinson | 31 | 12 | 12 1/2 | 12 1/2 | ...... | ...... | ...... | 1/2 | 1/2 | 1/2 | ... | ... | ... |
| Waiakea | 3 | 12 1/2 | 12 1/2 | 12 1/2 | ...... | ...... | ...... | 1/4 | 1/4 | 1/4 | ... | ... | ... |
| Hawi | 26 | 10 1/2 | 11 1/2 | 11 1/2 | 11 1/2 | ...... | ...... | 1/2 | 3/4 | 3/4 | 3/4 | ... | ... |
| Kaiwiki | 32 | 12 1/2 | 12 1/4 | 11 | ...... | ...... | ...... | 3/8 | 3/8 | 5/8 | ... | ... | ... |
| Waianae | 9 | 13 | 13 | 12 1/2 | 13 | ...... | ...... | 3/4 | 5/8 | 5/8 | 9/16 | ... | ... |
| Kohala | 40 | 12 1/2 | 12 1/4 | 9 1/4 | ...... | ...... | ...... | 1/2 | 1/4 | 1/8 | ... | ... | ... |
| Kilauea | 23 | 11 1/2 | 11 1/2 | 12 1/8 | ...... | ...... | ...... | 3/8 | 5/8 | 1/2 | ... | ... | ... |
| Kaeleku | 47 | 12 3/4 | 12 | 12 1/2 | ...... | ...... | ...... | 1/2 | 1/2 | 1/2 | ... | ... | ... |
| Waimanalo | 1 | 11 1/4 | 11 1/4 | 11 1/4 | ...... | ...... | ...... | 1/2 | 1/2 | 1/2 | ... | ... | ... |
| Union Mill | 11 | 11 | 11 1/4 | 11 | ...... | ...... | ...... | 3/4 | 1 | 1 | ... | ... | ... |
| Halawa | 29 | 10 1/2 | 10 1/2 | ...... | ...... | ...... | ...... | 5/16 | 5/16 | ... | ... | ... | ... |
| Waimea | 4 | 9 | 11 | 10 | 10 | ...... | ...... | 1/2 | 1/4 | 1/2 | 1/4 | ... | ... |
| Olowalu | 18 | 10 | 11 1/4 | 11 1/2 | ...... | ...... | ...... | 1/2 | 3/8 | 1/4 | ... | ... | ... |
| Niulii | 39 | 12 | 10 1/4 | 12 | ...... | ...... | ...... | 5/8 | 13/16 | 1 1/4 | ... | ... | ... |

**Speed of Rollers — Feet per Minute; Pressure on Rollers — Tons**

| Factory | Factory No. | Speed Crusher | Speed 1st Mill | Speed 2nd Mill | Speed 3rd Mill | Speed 4th Mill | Speed 5th Mill | Speed 6th Mill | Pressure Crusher | Pressure 1st Mill | Pressure 2nd Mill | Pressure 3rd Mill | Pressure 4th Mill | Pressure 5th Mill | Pressure 6th Mill | Tons Cane per Hour | Tonnage Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co. | 6 | 30 | 25 | 27.5 | 30.3 | 32 | .... | .... | 300 | 420 | 450 | 475 | 525 | .... | .... | 65.12* | 1.85 |
| " " | 6 | 30 | 25 | 27.5 | 30.3 | 32 | .... | .... | 300 | 420 | 450 | 475 | 525 | .... | .... | | |
| Oahu | 20 | 37 | 25.4 | 17.6 | 19.5 | 21 | .... | .... | 218 | 454 | 454 | 517 | 470 | .... | .... | 60.22* | 1.71 |
| " | 20 | 37 | 25.4 | 17.6 | 19.5 | 21 | .... | .... | 307 | 328 | 318 | 387 | 447 | .... | .... | | |
| Ewa | 5 | 20.7 | 19.7 | 22 | 23.7 | 25.7 | 29.2 | 33.3 | 370 | 450 | 450 | 400 | 400 | 400 | 450 | 84.96 | 1.72 |
| Waialua | 17 | 23.5 | 22 | 18.5 | 21 | 22.5 | .... | .... | 300 | 440 | 420 | 480 | 490 | .... | .... | 64.90 | 1.84 |
| Pioneer | 10 | 51.9 | 30.1 | 31.3 | 23.9 | 27.3 | 31.4 | .... | 285 | 481 | 425 | 331 | 340 | 359 | .... | 78.25 | 2.17 |
| Olaa | 36 | .... | 24.7 | 25.6 | 29.3 | 33.7 | .... | .... | .... | 410 | 350 | 330 | 420 | .... | .... | 57.28 | 2.03 |
| Haw. Sug. | 16 | 28 | 17.6 | 19.8 | 19.6 | 21.1 | .... | .... | 300 | 498 | 490 | 490 | 502 | .... | .... | 49.56 | 1.41 |
| Maui Agr. | 21 | 23 | 23.5 | 25.5 | 28.8 | 23.5 | 25.3 | 28.8 | 450 | 340 | 350 | 486 | 260 | 230 | 380 | 77.62 | 2.20 |
| Lihue | 27 | 34.2 | 19.7 | 19.3 | 21.4 | 23.8 | .... | .... | 290 | 470 | 410 | 430 | 460 | .... | .... | 63.62 | 1.81 |
| Onomea | 34 | 29.8 | 23.2 | 23.2 | 23.2 | 23.2 | .... | .... | .... | 428 | 400 | 400 | 400 | .... | .... | 47.63 | 1.89 |
| Hilo | 33 | 27.6 | 19.5 | 22 | 24.6 | 13.9 | .... | .... | .... | 350 | 395 | 395 | 430 | .... | .... | 40.53 | 1.61 |
| Kekaha | 25 | 21 | 16 | 17.7 | 19 | 20 | 20 | .... | .... | 320 | 315 | 348 | 328 | 356 | .... | 39.59 | 1.58 |
| Honolulu | 13 | 19.7 | 18.6 | 21.2 | 21.8 | .... | .... | .... | 250 | 450 | 430 | 430 | .... | .... | .... | 43.43 | 1.54 |
| Haw. Agr. | 30 | 21.5 | 20 | 17.5 | 19.5 | 21.8 | .... | .... | 355 | 398 | 461 | 370 | 400 | .... | .... | 47.94 | 1.90 |
| Hakalau | 7 | 30.5 | 21.6 | 24.2 | 26.5 | 15.8 | .... | .... | .... | 322 | 322 | 345 | 380 | .... | .... | 32.33 | 1.55 |
| Wailuku | 2 | 31.7 | 19.4 | 16.8 | 17.8 | 22.3 | .... | .... | .... | 400 | 370 | 360 | 380 | .... | .... | 40.61 | 1.15 |
| Makee | 14 | 25.9 | 22.5 | 25.7 | 29.5 | .... | .... | .... | 250 | 450 | 475 | 475 | .... | .... | .... | 49.17 | 2.05 |
| McBryde | 12 | 26 | 18 | 18 | 18 | .... | .... | .... | 250 | 400 | 503 | 525 | .... | .... | .... | 39.63 | 1.21 |
| Honokaa | 35 | 27.1 | 19.5 | 16.9 | 20.5 | 22.6 | .... | .... | 195 | 292 | 265 | 283 | 357 | .... | .... | 39.03 | 1.55 |
| Laupahoehoe | 41 | 23.2 | 16.4 | 17.6 | 18.9 | .... | .... | .... | 250 | 374 | 374 | 374 | .... | .... | .... | 27.24 | 1.63 |
| Pepeekeo | 19 | 31.4 | 17.9 | 19.7 | 21.6 | .... | .... | .... | .... | 380 | 380 | 380 | .... | .... | .... | 29.50 | 1.77 |
| Hamakua | 15 | 25 | 15.7 | 18.1 | 20.2 | 21.8 | .... | .... | .... | 360 | 316 | 333 | 370 | .... | .... | 29.80 | 1.43 |
| Kahuku | 43 | 25.5 | 15.4 | 17.6 | 20.3 | .... | .... | .... | 187 | 434 | 434 | 499 | .... | .... | .... | 33.46 | 1.39 |
| Paauhau | 24 | 23.6 | 14.5 | 17.1 | 19 | 21 | .... | .... | .... | 397 | 390 | 356 | 406 | .... | .... | 29.79 | 1.18 |
| Honomu | 37 | 21.1 | 18.3 | 21 | 23.3 | .... | .... | .... | 295 | 318 | 318 | 318 | .... | .... | .... | 26.78 | 1.61 |
| Koloa | 38 | 22.5 | 17.5 | 19 | 17.5 | 19 | .... | .... | 140 | 400 | 380 | 400 | 400 | .... | .... | 32.84 | 1.30 |
| Hutchinson | 31 | 27.6 | 17.2 | 19.2 | 21.2 | .... | .... | .... | .... | 420 | 400 | 400 | .... | .... | .... | 31.13 | 1.87 |
| Waiakea | 3 | 24.7 | 17.8 | 19 | 21.8 | .... | .... | .... | 150 | 330 | 295 | 330 | .... | .... | .... | 26.37 | 1.58 |
| Hawi | 26 | 16 | 18 | 16 | 18 | 18 | .... | .... | 170 | 170 | 242 | 259 | 333 | .... | .... | 24.55 | 1.45 |
| Kaiwiki | 32 | 22.3 | 17.5 | 19.9 | 22 | .... | .... | .... | .... | 301 | 318 | 335 | .... | .... | .... | 26.43 | 1.59 |
| Waianae | 9 | ... | 16.4 | 15.7 | 15.7 | 18.8 | .... | .... | .... | 287 | 291 | 291 | 340 | .... | .... | 25.87 | 1.55 |
| Kohala | 40 | 25 | 18 | 20 | 25 | .... | .... | .... | .... | 359 | 365 | 385 | .... | .... | .... | 26.21 | 1.57 |
| Kilauea | 23 | 18 | 19.5 | 26.5 | 20.5 | .... | .... | .... | 300 | 320 | 310 | 312 | .... | .... | .... | 25.6 | 1.54 |
| Kaeleku | 47 | 19.8 | 16.5 | 18.2 | 20.5 | .... | .... | .... | .... | 340 | 340 | 340 | .... | .... | .... | 28.65 | 1.72 |
| Waimanalo | 1 | 17.9 | 17.4 | 19.1 | 19.1 | .... | .... | .... | 348 | 348 | 348 | 348 | .... | .... | .... | 26.29 | 1.95 |
| Union Mill | 11 | ... | 13 | 17.4 | 16.3 | .... | .... | .... | .... | 262 | 295 | 300 | .... | .... | .... | 20.01 | 1.60 |
| Halawa | 29 | 12.8 | 16 | 11.2 | .... | .... | .... | .... | 165 | 172 | 186 | .... | .... | .... | .... | 13.52 | 1.56 |
| Waimea | 4 | 20.4 | 13.6 | 14.1 | 13.6 | 17 | .... | .... | .... | 215 | .... | 154 | 154 | .... | .... | 13.60 | 1.33 |
| Olowalu | 18 | 23.9 | 23.9 | 25.5 | 25.5 | .... | .... | .... | 202 | 202 | 220 | 220 | .... | .... | .... | 16.79 | 1.57 |
| Niulii | 39 | ... | 15.8 | 19.5 | 19.5 | .... | .... | .... | .... | 168 | 177 | 186 | .... | .... | .... | 17.04 | 1.68 |

*Tons of cane per hour for one tandem.
†6th Mill. Openings 1/4x0, returner bar from top roller, 1 1/2, 1 3/4, 1 7/8.
‡6th Mill. Openings 1/16x0, returner bar from top roller, center 1 3/8.

# CANE MILL DATA, SEASON OF 1925 (CONTINUED) ROLLER GROOVING

| Factory | Factory No. | MILLING PLANT | SURFACE GROOVES PER INCHES. TOP, FRONT, BACK. | | | | | | | Factory No. | JUICE GROOVES | | | | | | | | | | | | | | | | | | | | | | | | Factory No. | Factory |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | 1st Mill | | | | | | 2nd Mill | | | | | | 3rd Mill | | | | | | 4th Mill | | | | | | 5th Mill | | | | | | 6th Mill | | | | | | | |
| | | | | | | | | | | | Front | | | Back | | | Front | | | Back | | | Front | | | Back | | | Front | | | Back | | | Front | | | Back | | | Front | | | Back | | | | |
| | | | Crusher | 1st Mill | 2nd Mill | 3rd Mill | 4th Mill | 5th Mill | 6th Mill | | Width | Depth | Pitch | Width | Depth | Pitch | Width | Depth | Pitch | Width | Depth | Pitch | Width | Depth | Pitch | Width | Depth | Pitch | Width | Depth | Pitch | Width | Depth | Pitch | Width | Depth | Pitch | Width | Depth | Pitch | Width | Depth | Pitch | Width | Depth | Pitch | | |
| H. C. & S. Co. | 6 | K(2),2RC78,S72,12RM78 | Krajewski | 1 1/3, 1 1/3, 1 1/3 | 8, 1 1/3, 8 | 8, 1 1/3, 8 | 8, 1 1/3, 8 | | | 6 | 7/32 | 21/4 | 21/2 | —— | —— | —— | 7/32 | 21/4 | 21/4 | 7/32 | 13/4 | 2 | 7/32 | 21/4 | 21/4 | 7/32 | 13/4 | 4 | 7/32 | 21/4 | 21/4 | 7/32 | 13/4 | 3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 6 | H. C. & S. Co. |
| " " | 6 | K(2),2RC78,S72,12RM78 | Krajewski | 1 1/3, 1 1/3, 1 1/3 | 8, 1 1/3, 8 | 8, 1 1/3, 8 | 8, 1 1/3, 8 | | | 6 | 7/32 | 21/4 | 21/4 | 7/32 | 13/4 | 2 | 7/32 | 21/4 | 21/4 | 7/32 | 13/4 | 4 | 7/32 | 21/4 | 21/4 | 7/32 | 13/4 | 3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 6 | " " |
| Oahu | 20 | K,2RC78,S72,12RM78 | Krajewski | 2 2/3, 1 1/3, 2 2/3 | 2 2/3, 1 1/3, 2 2/3 | 2 2/3, 1 1/3, 2 2/3 | 7, 2 2/3, 7 | | | 20 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | 20 | Oahu |
| " " | 20 | K,2RC78,S72,12RM78 | Krajewski | 2 2/3, 1 1/3, 2 2/3 | 2 2/3, 1 1/3, 2 2/3 | 2 2/3, 1 1/3, 2 2/3 | 7, 2 2/3, 7 | | | 20 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | 5/16 | 2 | 3 3/4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | 20 | " " |
| Ewa | 5 | K(2),2RC78,1SRM78 | 1,1 | 1 1/3, 1 1/3, 1 1/3 | 2 2/3, 1 1/3, 2 2/3 | 2 2/3, 1 1/3, 5 1/3 | 2 2/3, 1 1/3, 5 1/3 | 5 1/3, 1 1/3, 5 1/3 | | 5 | 9/32 | 13/4 | 3 | 5/32 | 11/2 | 3 | 9/32 | 13/4 | 3 | 5/32 | 11/2 | 3 | 9/32 | 13/4 | 3 | 5/32 | 11/2 | 3 | 9/32 | 13/4 | 3 | 5/32 | 11/2 | 3 | 9/32 | 13/4 | 3 | 5/32 | 11/2 | 3 | 9/32 | 13/4 | 3 | 5/32 | 11/2 | 3 | 5 | Ewa |
| Wailua | 17 | K(2),2RC78,12RM78 | 4/5, 4/5 | 1 1/3, 1 1/3, 1 1/3 | 1 1/3, 1 1/3, 1 1/3 | 2 2/3, 1 1/3, 2 2/3 | 2 2/3, 1 1/3, 2 2/3 | | | 17 | 3/8 | 13/4 | 4 1/2 | 3/8 | 13/4 | 4 | 5/16 | 2 | 4 | 5/16 | 2 | 4 | 5/16 | 2 | 4 | 3/16 | 2 | 3 | 3/16 | 2 | 3 | 3/16 | 2 | 3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 17 | Wailua |
| Pioneer | 10 | K,2RC72,S72,15RM72 | Krajewski | 1 1/3, 1 1/3, 1 1/3 | 7, 1 1/3, 7 | 7, 1 1/3, 7 | 7, 1 1/3, 7 | 7, 1 1/3, 7 | | 10 | 3/16 | 2 | 2 1/4 | 3/16 | 2 | 2 1/4 | 3/16 | 2 | 2 1/4 | 3/16 | 2 | 2 1/4 | 3/16 | 2 | 2 1/4 | 3/16 | 2 | 2 1/4 | 3/16 | 2 | 2 1/4 | 3/16 | 2 | 2 1/4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | 10 | Pioneer |
| Olaa | 36 | K,ST2,12RM78 | .... | 2 3/4, 3, 6 | 6, 3, 6 | 6, 3, 6 | 6, 2 2/3, 6 | | | 36 | 3/16 | 13/8 | 3 | 3/16 | 13/8 | 3 | 3/16 | 13/8 | 3 | 3/16 | 13/8 | 3 | 3/16 | 13/8 | 5 | 3/16 | 13/8 | 5 | 3/16 | 13/8 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 36 | Olaa |
| Haw. Sug. | 16 | K,2RC72,S72,12RM78 | Krajewski | 4, 4, 7 | 6, 4, 6 | 4, 4, 4 | 7, 7, 7 | | | 16 | 1/4 | 11/2 | 2 | 5/32 | 11/4 | 2 | 1/4 | 11/2 | 2 | 5/32 | 11/4 | 2 | 1/4 | 11/2 | 2 | 5/32 | 11/4 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 16 | Haw. Sug. |
| Maui Agr. | 21 | K(2),3RC66,18RM66 | .... | 1 1/2, 1 1/2, 1 1/2 | 6, 6, 6 | 6, 6, 6 | 6, 6, 6 | 6, 6, 6 | 6, 6, 6 | 21 | 5/16 | 11/2 | 3 | 5/16 | 11/2 | 3 | 5/16 | 11/2 | 3 | 5/16 | 11/2 | 3 | 5/16 | 11/2 | 3 | 5/16 | 11/2 | 3 | 5/16 | 11/2 | 3 | 5/16 | 11/2 | 3 | 5/16 | 11/2 | 3 | 5/16 | 11/2 | 3 | 5/16 | 11/2 | 3 | 21 | Maui Agr. |
| Lihue | 27 | K,2RC78,S72,12RM78 | Krajewski | 1 1/3, 1 1/3, 2 2/3 | 7, 1 1/3, 7 | 5, 1 1/3, 7 | 5, 1 1/3, 5 | | | 27 | 1/4 | 2 | 3 | 1/4 | 11/4 | 2 1/4 | 1/4 | 13/4 | 3 | 1/4 | 11/4 | 2 1/4 | 1/4 | 13/4 | 3 | 1/4 | 11/2 | 2 1/2 | 1/4 | 11/4 | 3 | 1/4 | 11/4 | 2 3/8 | .... | .... | .... | .... | .... | .... | .... | .... | .... | 27 | Lihue |
| Onomea | 34 | 2RC60,S54,12RM66 | Krajewski | 7, 5, 7 | 7, 4, 7 | 7, 4, 7 | 7, 4, 7 | | | 34 | 1/4 | 11/2 | 2 | 3/16 | 11/2 | 2 | 1/4 | 13/4 | 2 | 3/16 | 13/4 | 2 | 1/4 | 13/4 | 2 | 5/32 | 13/4 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 34 | Onomea |
| Hilo | 33 | K,2RC60,12RM66 | Krajewski | 2 1/2, 2 1/2, 5 | 5, 5, 5 | 5, 5, 5 | 5, 5, 5 | | | 33 | 1/4 | 2 | 2 1/2 | 1/8 | 13/8 | 1 3/5 | 1/4 | 2 | 2 1/2 | 1/8 | 13/8 | 1 3/5 | 1/4 | 2 | 2 | 1/8 | 13/8 | 2 | 1/4 | 2 | 3 | 1/8 | 13/8 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | 33 | Hilo |
| Kekaha | 25 | 2RC54,15RM60 | Krajewski | 8/9, 8/9, 8/9 | 7, 6, 7 | 7, 6, 7 | 7, 6, 7 | 7, 7, 7 | | 25 | —— | —— | —— | —— | —— | —— | 1/4 | 13/8 | 2 | 3/16 | 13/8 | 2 | 1/4 | 13/8 | 2 | 3/16 | 13/8 | 2 | 3/16 | 13/8 | 2 | 1/8 | 13/8 | 2 | 1/8 | 13/8 | 2 | .... | .... | .... | .... | .... | .... | 25 | Kekaha |
| Honolulu | 13 | K(2),S54,2RC78,9RM78 | 2/3, 2/3 | 1 1/3, 1 1/3, 1 1/3 | 6, 6, 6 | 6, 6, 6 | | | | 13 | —— | —— | —— | —— | —— | —— | 3/16 | 11/2 | 3 | 3/16 | 11/2 | 3 | 3/16 | 11/2 | 3 | 3/16 | 11/2 | 3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 13 | Honolulu |
| Haw. Agr. | 30 | 3RC60,12RM66 | 2/3, 2/3, 2/3 | 1 1/3, 1 1/3, 1 1/3 | 2 1/3, 2 1/2, 2 1/2 | 5, 1 1/3, 5 | 5, 1 3/5, 5 | | | 30 | 3/16 | 13/8 | 3 | 3/16 | 13/8 | 3 | 3/16 | 13/8 | 2 | 3/16 | 13/8 | 2 | 1/4 | 11/2 | 2 | 1/4 | 11/2 | 2 | 3/16 | 11/2 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 30 | Haw. Agr. |
| Hakalau | 7 | 2RC54,12RM9-60,3-66 | Krajewski | 5, 5, 5 | 7, 7, 7 | 7, 7, 7 | 7, 7, 7 | | | 7 | 1/4 | 11/2 | 2 | 1/8 | 11/2 | 2 | 1/4 | 11/2 | 2 | 1/8 | 11/2 | 2 | 1/4 | 11/2 | 2 | 1/8 | 11/2 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 7 | Hakalau |
| Wailuku | 2 | K,2RC72,12RM78 | Krajewski | 1 1/3, 1 1/3, 1 1/3 | 4, 4, 4 | 4, 4, 4 | 4, 4, 4 | | | 2 | 3/8 | 11/2 | 4 | 5/32 | 11/2 | 2 | 1/4 | 11/2 | 2 | 5/32 | 11/2 | 2 | 1/4 | 11/2 | 2 | 5/32 | 11/2 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2 | Wailuku |
| Makee | 14 | K,2RC72,S72,9RM72 | Krajewski | 3, 3, 7 | 3, 3, 7 | 7, 7, 7 | | | | 14 | 3/16 | 11/2 | 3 | 3/16 | 11/2 | 2 | 3/16 | 11/2 | 3 | 3/16 | 11/2 | 3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 14 | Makee |
| McBryde | 12 | K,2RC72,S72,9RM84 | Krajewski | 6, 1 1/3, 6 | 6, 6, 6 | 6, 6, 6 | | | | 12 | 5/16 | 11/2 | 3 | 1/4 | 11/2 | 2 1/4 | 1/4 | 11/2 | 3 | 1/4 | 11/2 | 2 1/2 | 3/8 | 11/2 | 3 | 5/16 | 11/2 | 2 1/2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 12 | McBryde |
| Honokaa | 35 | K(2),2RC66,12RM66 | 2/3, 2/3 | 4, 4, 2 | 5, 5, 5 | 4, 6, 5 | 5, 5, 5 | | | 35 | 3/4 | 11/2 | 2 | 5/16 | 2 | 2 | 7/16 | 2 | 2 | 5/16 | 11/2 | 2 | 5/16 | 11/2 | 2 | 7/16 | 11/4 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 35 | Honokaa |
| Laupahoehoe | 41 | K,2RC54,9RM60 | 3/4, 3/4 | 5, 4, 5 | 6, 4, 6 | 7, 4, 7 | | | | 41 | 5/16 | 11/2 | 2 3/4 | 1/4 | 11/2 | 2 3/4 | 5/16 | 11/2 | 3 | 1/4 | 11/2 | 3 | 1/4 | 11/2 | 2 3/4 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 41 | Laupahoehoe |
| Pepeekeo | 19 | 2RC54,9RM60 | Krajewski | 5, 7, 7 | 5, 7, 7 | 5, 7, 7 | 6, 6, 6 | 6, 6, 6 | | 19 | 1/4 | 11/4 | 3 | 1/8 | 11/2 | 1 1/2 | 1/4 | 11/4 | 3 | 1/8 | 13/4 | 1 1/2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 19 | Pepeekeo |
| Hamakua | 15 | K,2RC60,12RM60 | Krajewski | 6, 6, 6 | 6, 6, 6 | 6, 6, 6 | 6, 6, 6 | | | 15 | 1/4 | 11/2 | 2 1/4 | 1/4 | 11/4 | 2 1/4 | 1/4 | 11/4 | 2 1/4 | 1/4 | 11/4 | 2 1/4 | 1/4 | 11/2 | 2 | 1/4 | 11/4 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 15 | Hamakua |
| Kahuku | 43 | K,2RC60,S54,9RM72 | Krajewski | 4, 2, 4 | 4, 4, 4 | 4, 4, 4 | | | | 43 | —— | —— | —— | —— | —— | —— | 1/4 | 11/2 | 2 | 1/4 | 11/2 | 2 | 1/4 | 11/2 | 2 | 3/16 | 13/4 | 3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 43 | Kahuku |
| Paauhau | 24 | 2RC60,12RM66 | Krajewski | 4, 2 2/3, 4 | 4, 7, 7 | 4, 7, 7 | 4, 7, 7 | | | 24 | 1/8 | 11/2 | 2 | 1/8 | 11/4 | 2 | 1/8 | 11/2 | 2 | 1/8 | 11/4 | 2 | 1/8 | 11/2 | 2 | 1/8 | 11/4 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 24 | Paauhau |
| Honomu | 37 | 3RC60,9RM60 | 2/3, 2/3, 2/3 | 6, 6, 6 | 5, 6, 5 | 5, 6, 6 | | | | 37 | 5/32 | 13/4 | 2 | 5/32 | 13/4 | 2 | 5/32 | 13/4 | 2 | 5/32 | 13/4 | 2 | 5/32 | 13/4 | 2 | 5/32 | 13/4 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 37 | Honomu |
| Koloa | 38 | K,2RC60,12RM66 | Krajewski | 2 5/8, 2 5/8, 5 1/4 | 5 1/4, 2 5/8, 5 1/4 | 5 1/4, 2 5/8, 5 1/4 | 5 1/4, 2 5/8, 5 1/4 | | | 38 | 1/4 | 11/2 | 2 5/8 | 1/8 | 11/2 | 2 5/8 | 1/4 | 11/2 | 2 5/8 | 1/8 | 11/2 | 2 5/8 | 1/4 | 11/2 | 2 5/8 | 1/8 | 11/2 | 2 5/8 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 38 | Koloa |
| Hutchinson | 31 | 2RC60,9RM60 | 2/3, 2/3 | 5, 5, 5 | 5, 5, 5 | 5, 5, 5 | | | | 31 | 1/4 | 11/4 | 2 | 1/8 | 11/2 | 2 | 3/16 | 11/2 | 2 | 3/16 | 11/2 | 2 | 1/8 | 11/2 | 2 | 1/8 | 11/2 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 31 | Hutchinson |
| Waiakea | 3 | K,2RC60,9RM60 | Krajewski | 4, 4, 7 | 7, 4, 7 | 7, 4, 7 | | | | 3 | 1/4 | 11/2 | 2 1/2 | 1/4 | 11/2 | 2 1/2 | 5/8 | 13/4 | 3 1/2 | 1/4 | 11/2 | 2 1/2 | 1/4 | 11/2 | 2 1/2 | 1/4 | 11/2 | 2 1/2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3 | Waiakea |
| Hawi | 26 | K(2),2RC48,12RM3-48,9-54 | 3 1/2, 4/5, 3 | 3 1/2, 4/5, 3 | 3 1/2, 4/5, 3 1/2 | 3 1/2, 3 1/2, 3 | 3, 3 1/2, 3 1/2 | | | 26 | —— | —— | —— | —— | —— | —— | —— | —— | —— | 1/4 | 13/8 | 2 | 5/16 | 1 1/4 | 2 7/8 | 1/4 | 13/8 | 2 | 5/16 | 1 15/16 | 3 | —— | —— | —— | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 26 | Hawi |
| Kaiwiki | 32 | K,2RC60,9RM60 | Krajewski | 3, 3, 3 | 7, 7, 7 | 7, 7, 7 | | | | 32 | 1/4 | 11/2 | 3 | —— | —— | —— | 3/16 | 11/4 | 3 | 3/16 | 11/2 | 3 | 1/4 | 11/2 | 3 | —— | —— | —— | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 32 | Kaiwiki |
| Waianae | 9 | K(2),12RM60 | .... | 1, 1, 1 | 6, 1 3/5, 6 | 6, 6, 6 | | | | 9 | —— | —— | —— | —— | —— | —— | 3/16 | 11/4 | 2 | 3/16 | 11/4 | 2 | 5/16 | 11/4 | 2 | —— | —— | —— | 1/8 | 11/4 | 1 7/8 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 9 | Waianae |
| Kohala | 40 | K(2),3RC60,9RM60 | .... | 2 1/2, 2 1/2, 4 | 2 1/2, 2 1/2, 2 1/2 | 5, 4, 5 | 5, 5, 5 | | | 40 | 1/4 | 1 | 2 1/2 | 1/4 | 1 | 2 3/4 | 1/4 | 1 | 3 | 1/4 | 1 | 2 1/2 | 1/4 | 1 | 2 | 1/4 | 1 | 3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 40 | Kohala |
| Kilauea | 23 | K,S,3RC60,9RM60 | .... | 8/9, 8/9, 8/9 | 4, 4, 7 | 7, 4, 7 | 7, 4, 4 | | | 23 | 3/16 | 11/4 | 2 | 3/16 | 15/16 | 2 | 3/16 | 13/4 | 2 | 3/16 | 13/8 | 2 | 1/4 | 11/4 | 2 | 1/8 | 11/4 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 23 | Kilauea |
| Kaeleku | 47 | K,2RC54,9RM60 | .... | Krajewski | 3, 3, 3 | 5, 5, 5 | 5, 5, 5 | | | 47 | 1/4 | 11/2 | 2 | 1/8 | 11/4 | 2 | 1/4 | 11/2 | 2 | 1/8 | 11/4 | 2 | 1/4 | 11/2 | 3 | 1/8 | 11/4 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 47 | Kaeleku |
| Waimanalo | 1 | K,2RC54,9RM54 | .... | 2/3, 2/3, 2/3 | 4, 4, 4 | 4, 4, 4 | 4, 4, 4 | | | 1 | 5/32 | 11/2 | 2 | 5/32 | 11/2 | 2 | 5/32 | 11/2 | 2 | 5/32 | 11/2 | 2 | 5/32 | 11/2 | 2 | 5/32 | 11/2 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | Waimanalo |
| Union Mill | 11 | K,9RM60 | .... | 2 1/4, 2 | 6, 2, 6 | 6, 2, 6 | | | | 11 | —— | —— | —— | 3/8 | 1 | 3 | 3/8 | 1 | 3 | 3/8 | 1 | 3 | 3/8 | 1 | 3 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 11 | Union Mill |
| Halawa | 29 | K,2RC60,6RM50 | .... | 8/9, 8/9 | 4, 4, 4 | 4, 4, 4 | | | | 29 | 1/4 | 11/2 | 2 | 1/4 | 11/2 | 2 | 1/8 | 11/2 | 2 | 1/8 | 11/2 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 29 | Halawa |
| Waimea | 4 | 2RC48,12RM42 | .... | Krajewski | 8/9, 8/9, 8/9 | 4, 4, 8 | 8, 4, 8 | 8, 4, 8 | | 4 | —— | —— | —— | —— | —— | —— | 3/16 | 11/4 | 2 | 5/16 | 11/2 | 2 | 1/8 | 11/2 | 2 | 5/16 | 11/2 | 2 | 1/8 | 11/2 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4 | Waimea |
| Olowalu | 18 | K,3RC48,9RM48 | .... | 2/3, 2/3, 2/3 | 5, 5, 5 | 5, 5, 5 | 5, 5, 5 | | | 18 | 3/16 | 11/4 | 2 | 3/16 | 11/4 | 2 | 3/16 | 11/4 | 2 | 3/16 | 11/2 | 2 | 3/16 | 11/2 | 2 | —— | —— | —— | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 18 | Olowalu |
| Niulii | 39 | K,9RM54 | .... | .... | 2, 2 1/2, 2 | 3 1/2, 2 3 1/2, 3 1/2 | 0, 6, 8 | | | 39 | 1/4 | 11/8 | 3 | 1/4 | 11/8 | 3 | 1/4 | 13/16 | 3 | 1/4 | 11/4 | 3 | 1/4 | 13/8 | 3 | —— | —— | —— | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 39 | Niulii |